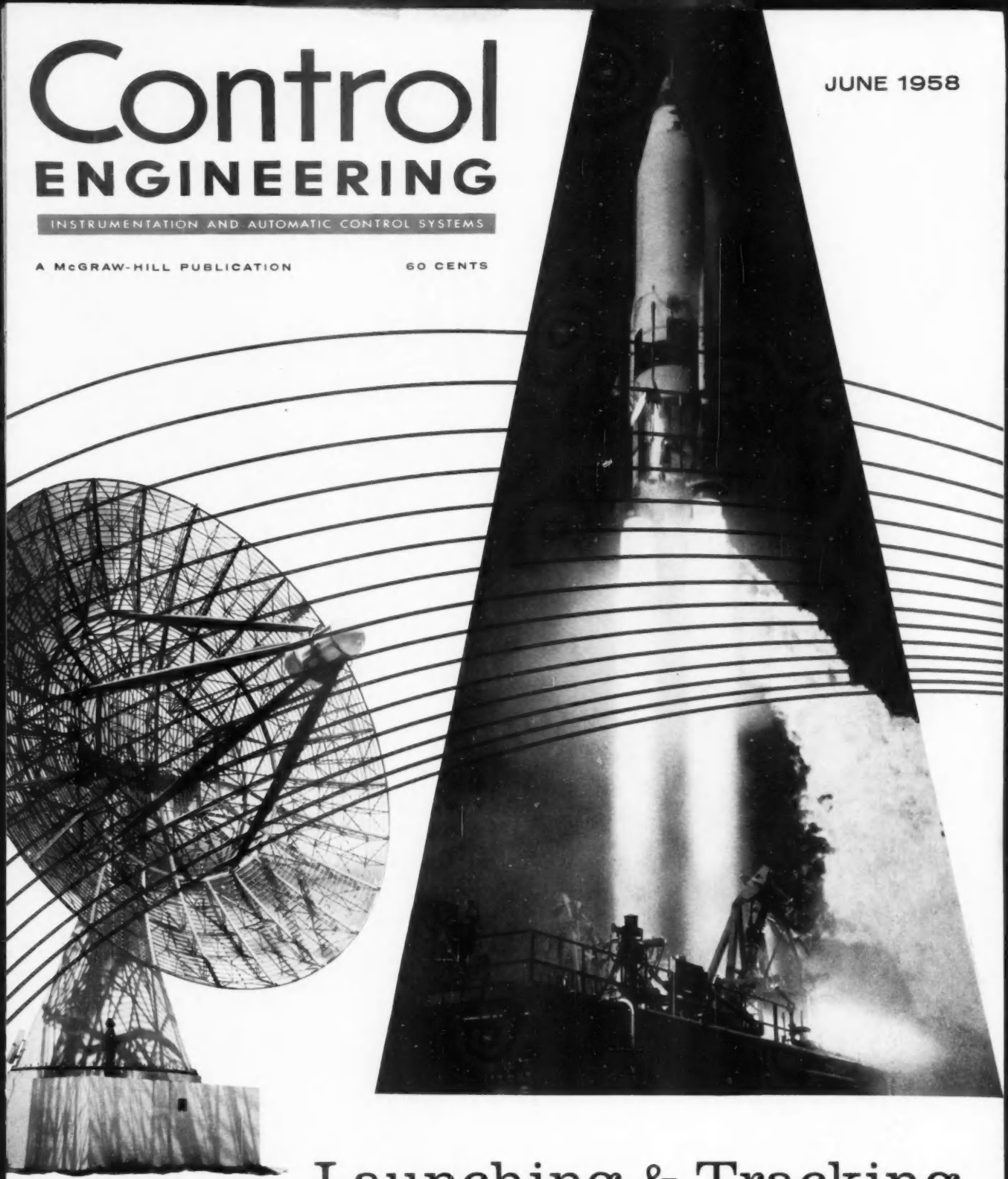
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

60 CENTS

JUNE 1958



Launching & Tracking at Cape Canaveral

Computing Components/ Instrumentation and Controls

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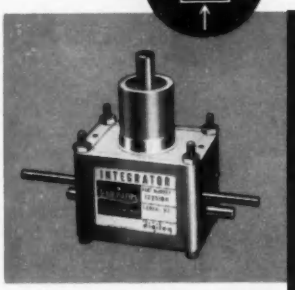
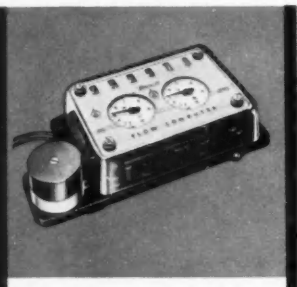
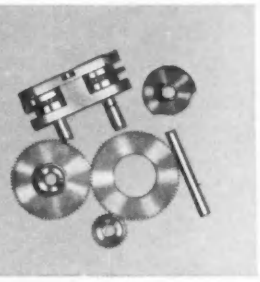


Ball-Disc Integrator... for use in totalizing, rate determination, differential analyzers, or as a closed loop servo-element... 0.01%V(av) optimum reproducibility.

Linear Integrator... for systems or instruments requiring integration, average computations, direct or remote reading... mounted on chart recorder.

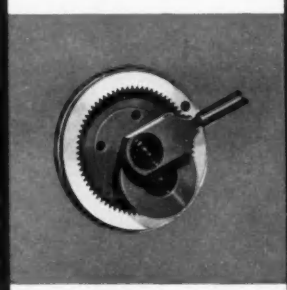


Flow Computer... extracts square root and continuously integrates both differential and static pressures for applications such as orifice measurement of fluids.



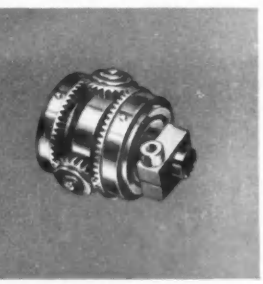
Custom Gears, Limit Stops, Shafts, Coupling and Cams... for computer, servomechanisms and instrument applications.

Analog Digital Converters... for converting shaft position to digital information available in Binary, Gray code or Binary decimal. Also Sine Cosine functions.

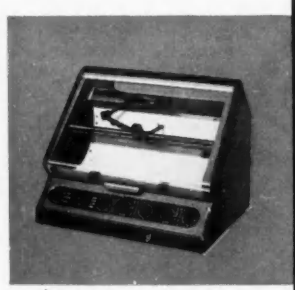


Sine Cosine Mechanism... for problems of changing variables involving vector components, range and bearing computations, sight computation, etc.

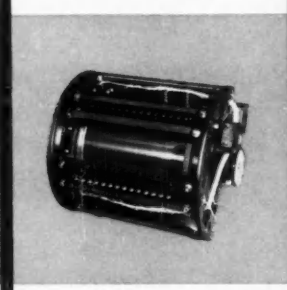
Linkages... for computing equipment; precision addition, subtraction linkages; multiplying linkages and function generators with displacement outputs.



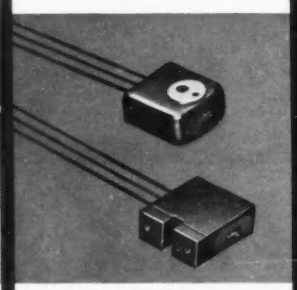
Hollow Shaft Differential... offers greater versatility in summing angular shaft positions; Hollow Shaft reduces breadboard and production costs.



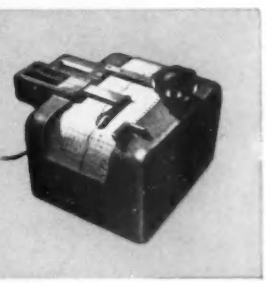
X-Y Plotter and Recorder... for point or continuous plotting, with positive mechanical drive in recording graphic data. Several models and accessories available.



Magnetic Storage Drum... for medium storage applications; capacity 131, 072 non-volatile bits; drum speed 3800 rpm; clock frequency 130 kc.



Read-Record Heads... for high frequency, non-contact recording applications in magnetic memory systems; high read back signals.



Planimeters... for miniature strip chart recorders for simple integration with variable speed control; 2 models: square root and linear.

There are available catalog sheets, bulletins or folders on all our products.

RELIABILITY is the prime consideration in the design and construction of the extensive line of Librascope products—the result of 20 years in the successful manufacture of mechanical, magnetic, optical, electronic and electrial instruments for military, research and commercial uses.

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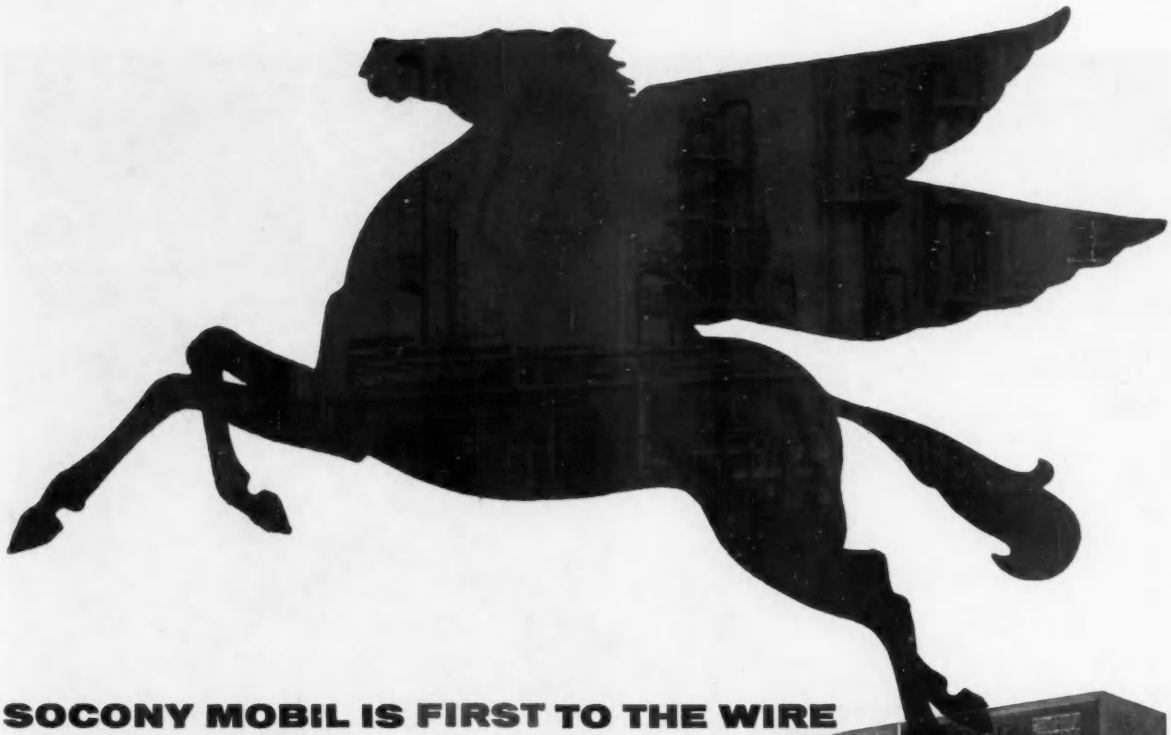

SOCONY MOBIL IS FIRST TO THE WIRE

with a major refining process chiefly dependent on an automatic data processing system...

the Beckman 112

When Socony Mobil decided to add a new multi-million-dollar catalytic reforming unit to their existing plant at Casper, Wyoming, they played a systems favorite. They put their instrumentation money on Beckman Systems Division.

Going on-stream to push out 3,000 barrels of hi-octane a day, Socony Mobil couldn't take chances with an untried instrumentation system. And yet, because they were investing in the future, they couldn't afford to put their money on the past.

Socony Mobil's decision was obvious: they had to have the very latest in a data processing system without sacrificing old-fashioned reliability. Only one data system seemed to offer daring new design and solid-state circuitry backed up by hardware already system-tested and proved in on-stream operation... *It was the Beckman 112, designed and built for continuous, twenty-four-hour, seven-day-a-week service in the process industries.*

The Socony Mobil handicappers were so sure they had picked a winner that they decided to build the *first* major on-stream process unit with normal operations dependent on an automatic data system. The Beckman-Socony Mobil entry eliminates almost all of the expensive duplication of conventional, parallel, back-up recording instrumentation.

You can't be first, too, but you can still be in the money. Why not ask a Beckman Systems Engineer to consult with you on your process instrumentation problems? And be sure to write for your copy of the illustrated brochure on the Beckman 112. Ask for Data File 3D-17-46.

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Control ENGINEERING

JUNE 1958 VOL. 5 NO. 6

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

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Control ENGINEERING

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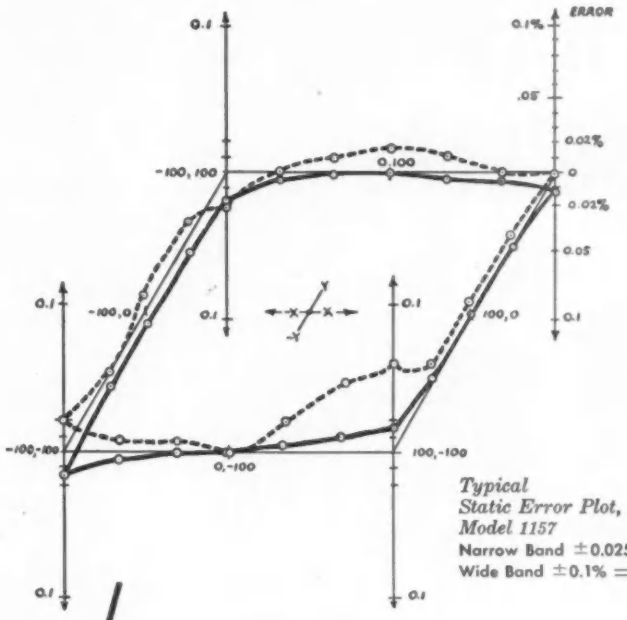
Linear Accuracy



Typical
Static Error Plot,
Model 1157
Narrow Band ±0.025% = ——
Wide Band ±0.1% = - - - -

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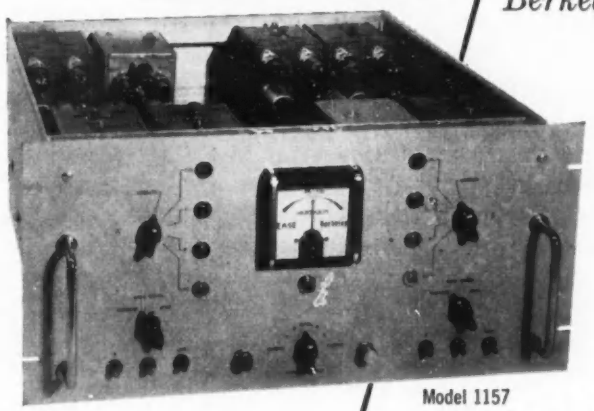
ELECTRONIC MULTIPLIER



Model 1157
Dual Electronic Multiplier

Beckman/Berkeley's Model 1157 electronic multiplier provides for the first time a unit offering both high accuracy and wide frequency response. It is the most accurate tool available for multiplying two varying voltages in the range of +100 to −100 volts. In addition, the carrier frequency of Model 1157 may be increased, providing greater band width for the output variable.

Another important feature of the new EASE* multiplier is its versatility. By energizing a relay within Model 1157, the unit becomes a divider without the use of any external components. Furthermore, its internal amplifiers may be used as operational amplifiers at the user's discretion, increasing the capacity of existing equipment. These internal amplifiers are chopper stabilized for low drift. Rugged construction, the extensive use of premium components and plug-in modules, including amplifiers and switching circuitry, simplify maintenance and improve reliability.

SPECIFICATIONS

STATIC ACCURACY
NARROW BAND RANGE: Product accurate to better than 0.01% of full scale in any one quadrant (full scale = 200 volts). Product accurate to better than 0.025% of full scale in all four quadrants.
WIDE BAND RANGE: Product accurate to better than 0.05% of full scale in any one quadrant. Product accurate to better than 0.1% of full scale in all four quadrants.

DRIFT
NARROW BAND RANGE: Less than 20MV (0.01% of full scale) over any 6-8 hour period.
WIDE BAND RANGE: Less than 60MV (0.03% of full scale) over any 6-8 hour period.

DIVIDER OPERATION
Provides circuitry for converting each multiplier channel to a divider by energizing a relay from patchboard. Output = 100X/Y; Y negative.

AMPLIFIER USE AS INVERTERS
Patchboard energizing of a relay allows the three Model 1048B Amplifiers per channel to be used as inverters when unit is not being used as a multiplier.

Complete technical specifications on the Model 1157 Dual Electronic Multiplier are available on request. Please address Dept. L-6.

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SHOPTALK

Progress in automatic programming

In the October 1956 issue of CtE, Arnold Siegel of MIT discussed the initial efforts to automatically program numerically-controlled machine tools by means of a general-purpose computer. This was at MIT, under Air Force contract. Here, Whirlwind translated simply coded drawing and cutting information into a form acceptable to the numerical director, saving many hours of tedious computation. Since that time, these techniques have traveled from the university to the factory, and modifications of the original procedures are now being used by several aircraft companies.

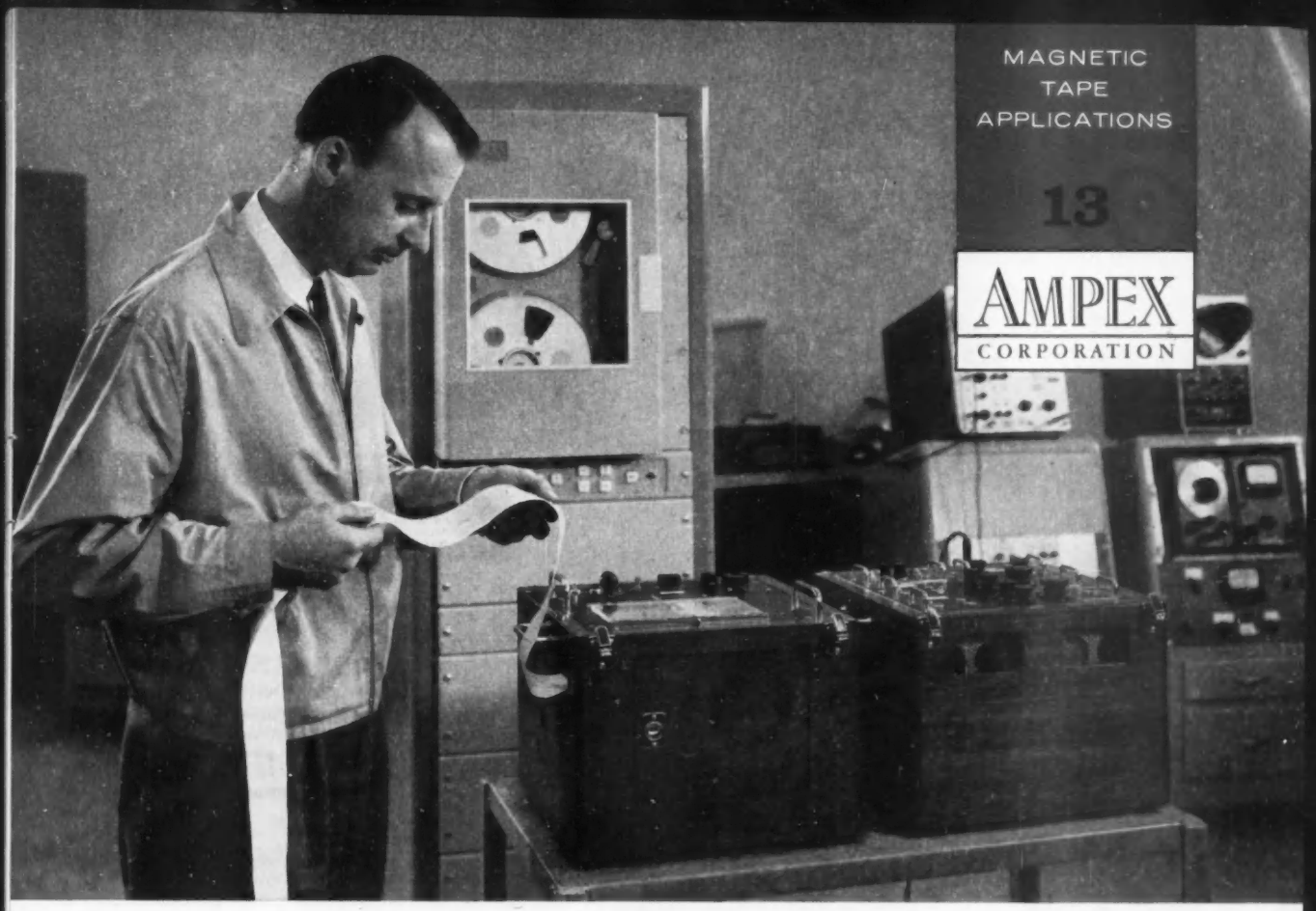
On page 101 Joe Albert and his group from the Georgia Div. of Lockheed Aircraft describe a production-proven modification of Siegel's contribution, using the widely available IBM 704. Future issues will discuss the best types of numerical-control computer programs for various applications, and the current cooperative work on three-dimensional programs. These articles represent some of the steps in our plans to keep CtE readers up-to-date in this area.

Young rides again

This time Associate Editor Lew Young headed south to spend four days at Patrick Air Force Base and Cape Canaveral in Florida. He always manages to arrange these trips so that they take him out of the inclement northland into the balmy southland at the right time of year. And on this trip he was really in luck: he attended an Atlas firing, watching it from a grandstand on the cape two miles from the launching pad (too close, says Lew). He also managed to collect a copious amount of data on the launching and tracking instrumentation at this ballistic missile test range. For the details, see page 79.

Karp at the podium

Associate Editor Harry Karp, the self-dubbed "silent chairman" (of the recent ISA New Jersey Section symposium on Control Systems Engineering), found he had to do a little talking at this event. Here he's shown introducing the panel members—selected from chemical, petroleum, and contracting firms—for the session of implementing control systems engineering. The grin on Harry's face reflects symposium success: a turnout of 325, proceedings ready on time, and a good steak dinner.



How to write 10,000-cycle data on a pen recorder

A tape tie-in banishes frequency-response limitations and saves paper

We will cancel the laws of physics, throw out inertia, and behold here is a pen recorder writing out 10,000 cycles per second ready to read. Don't scoff. There is a way. Assuming visual data is really what you want, keep your eye on the oscillograph or pen recorder, and think of the tape recorder as an ingenious "frequency-response extender" or "data stretcher."

A SLOW-MOTION LOOK AT TRANSIENTS

When an aircraft manufacturer was having shock problems from the firing of an experimental plane's armament, nothing could be seen in real-time data. For a better look, shock waves were recorded on tape, slowed down, recopied and then written out in visual traces. A thousandth of a second was stretched out to a full second. The exact extent and nature of the shock pattern and its manner of transmittal through the plane's structure became clearly evident – and with it the design solution.

100-TO-1 DATA STRETCHOUT (and more)

Compared to any visual-trace recorder, an Ampex instrumentation tape recorder has virtually unlimited response. Frequency components as high as 10,000 cycles per second (and much more) are easily recorded. And tape has decided advantages too at 1000 or 2000 cycles. A tape speed of 60 inches per second captures any of these higher frequencies and has tremendous room for slowdown on playback. Reproducing the tape at 0.6 in/sec. reduces 10,000 cps. to a mere 100. Connect a direct-writing recorder to the tape recorder and 100 cycles response is all that you need.

Actually Ampex has a wide range of tape speeds and tape slowdown ratios available. Tapes can be recopied once or even twice multiplying these ratios accordingly.

TYPICAL TAPE SLOWDOWN (OR SPEEDUP) RATIOS			
AMPEX MODEL	Basic speed ratio	First recopy	Second recopy
FR-1100	8 to 1	64 to 1	512 to 1
FR-100	32 to 1	1024 to 1	32,768 to 1
FR-1100 multirange (many versions available)	100 to 1	10,000 to 1	1,000,000 to 1

24 TIMES AS MUCH RECORDING TIME

On 5000-cycle data, an ordinary 10½" reel of 1-mil magnetic tape will record 24 minutes. On a visual-trace recorder writing 100 cycles per inch, a 250-foot magazine of expensive paper would last just one minute! When you record data first on tape, you will seldom recopy the whole test onto paper. With an oscilloscope or other scanning device, you find the important parts of the tape and copy as little as a few seconds onto the visual medium. The tape can be stored for future reference, cut into loops for analysis or can be erased and reused. It saves hundreds of feet of paper.

Because magnetic-tape data is an "electrical analog", it can also be used for automatic frequency analysis, computer input, simulation of phenomena and scanning, counting and correlating techniques. We have told the whole magnetic-tape story in a well illustrated and diagrammed 16-page brochure. For your copy, write Dept. HH-13.

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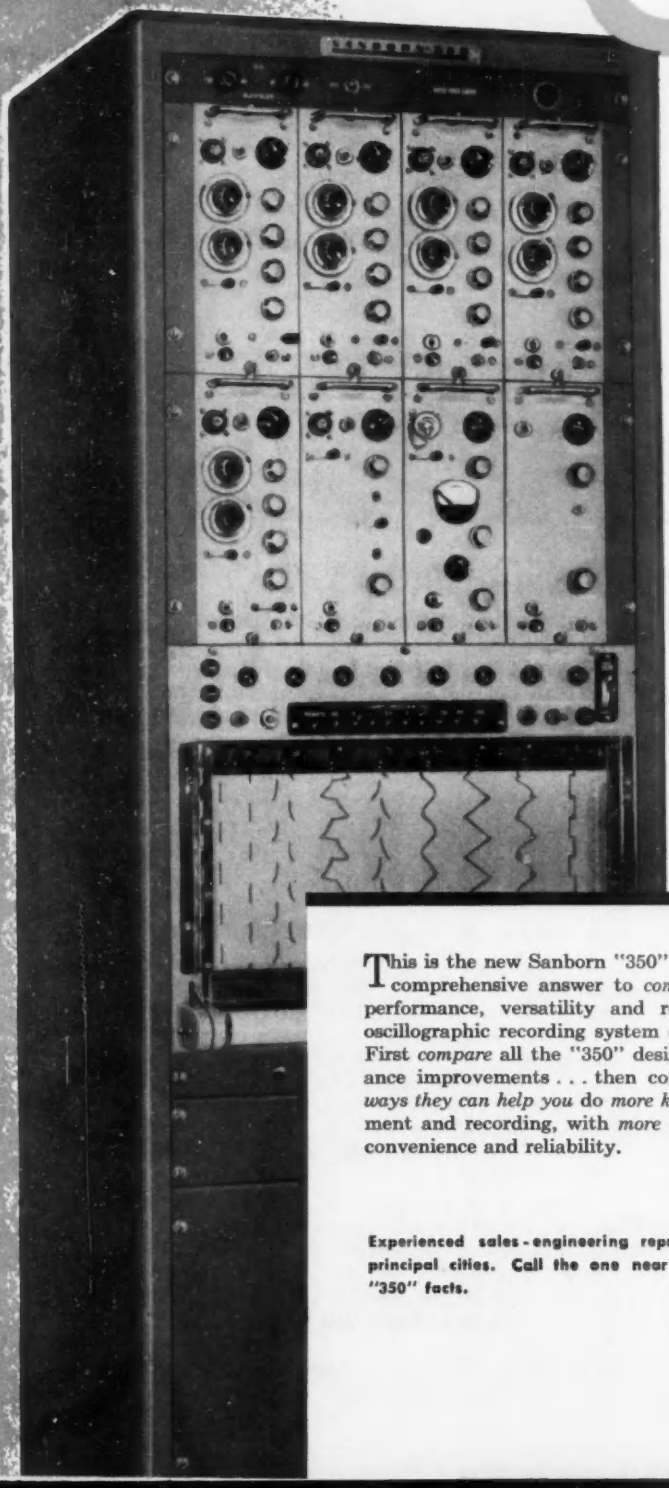
Phone your Ampex data specialist for personal attention to your recording needs. Offices serve U. S. A. and Canada. Engineering representatives cover the free world.

only one direct writer

THE NEW SANBORN 350



6- OR 8-CHANNEL OSCILLOGRAPHIC RECORDING SYSTEM

6- OR 8-CHANNEL SYSTEM IN ONE CABINET

Each module of four Preamplifiers takes only 10½" of panel space, complete Recorder-Power Amplifier package only 17½". All controls are on front panel. Total panel space, including ventilating fan and master power panel, 49". Entire system normally installed in one cabinet 22" x 22" x 73¾", to place recorder and controls at convenient height.

FREQUENCY RESPONSE TO 120 CPS

Essentially flat from 0 to 100 cps at 10-division amplitude peak-to-peak, 3 db down at 120 cycles. Built-in pre-emphasis circuit in Power Amplifier.

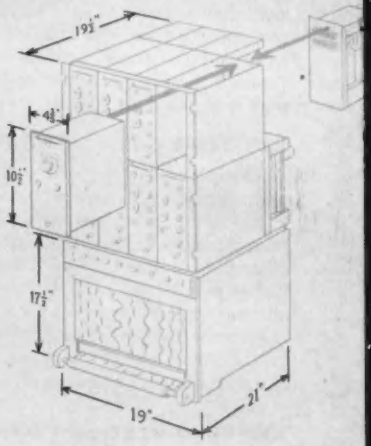
HEAVY CURRENT FEEDBACK, TRANSISTORIZED POWER AMPLIFIERS

Long term drift less than 0.2 div. over 20°C. changes, short term less than 0.1 div. for 24 volt line voltage changes. Response time 4 ms. In-phase rejection ratio 100:1. Gain stability better than 1% with 20°C. and 20 volt changes.

LINEARITY: 0.2 DIVISION OVER ENTIRE 50 DIV. CHART WIDTH

This is the new Sanborn "350" — today's most comprehensive answer to *combined* improved performance, versatility and reliability in an oscillographic recording system of compact size. First *compare* all the "350" design and performance improvements . . . then consider *the many ways they can help you* do *more kinds* of measurement and recording, with *more* accuracy, speed, convenience and reliability.

Experienced sales-engineering representatives in all principal cities. Call the one near you for complete "350" facts.



gives you all these features

INTERCHANGEABLE PREAMPLIFIERS WITH INDIVIDUAL POWER SUPPLIES

Compact, plug-in units with 4⅝" x 10½" panels. Present types include Carrier, Servo Monitor (demodulator), DC Coupling, True Differential DC. Can be used separately for driving optical oscillographs, 'scopes, tape recorders, etc.

LIMITER CIRCUIT AHEAD OF POWER AMPLIFIERS ASSURES DAMPING AT ALL TIMES

Limiting at input prevents amplifier saturation or cut off; so that galvanometer damping is never lost.

RUGGED, RELIABLE, LOW VOLTAGE, LOW IMPEDANCE GALVANOMETERS

Fewer turns of heavier wire and completely enclosed coil increase reliability. High torque (250,000 dyne-cm.). Hysteresis level less than 0.1 division. Designed for easy replacement in field.

RECORDER-POWER AMPLIFIER PACKAGE IN ONLY 17½" OF PANEL SPACE

Integral, tube-free package includes eight power amplifiers and power supply, which use power transistors and solid state rectifiers. Operates on 115 volts, 60 cycles. Simple paper loading from front. Individual stylus heat controls, chart speed pushbuttons, motor switch, timer-marker switch, fuses, paper footage indicator all on front panel. Connectors for input signals, output monitoring (±1 volt with respect to ground from 2.5 ohm source) and complete remote control provided at rear.

VELOCITY FEEDBACK DAMPING

True damping by velocity signal from separate winding over galvanometer driving coil. Damping control accessible from front of Recorder for easy adjustment.

(ALL DATA SUBJECT TO CHANGE WITHOUT NOTICE)

GALVANOMETER NATURAL FREQUENCY 55 CPS

Higher natural frequency provides higher over-all system frequency response.

INKLESS RECORDINGS IN TRUE RECTANGULAR COORDINATES

Heated stylus creates sharp, smudge-proof trace on plastic coated Permapaper. Chart channel width 1⅞" (approx. 4 cm), ruled in 50 div. of 1/32" each.

RECORDER-AMPLIFIER UNIT HAS 0.1 VOLT/CHART DIV. SENSITIVITY

Can be used alone, when preamplification is not needed. (Three complete 8-channel Recorder-amplifier-power supply units can be mounted in one cabinet.)

ELECTRICAL PUSHBUTTON CHART SPEED CONTROL, WITH PROVISION FOR REMOTE CONTROL

Any of nine speeds (0.25, 0.5, 1.0, 2.5, 5, 10, 25, 50, 100 mm/sec.) instantly selectable by pushbutton. Plastic strip for channel identification markings.

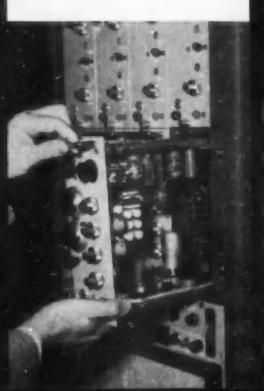
QUALITY COMPONENTS USED THROUGHOUT

JAN components used wherever practicable; for example, note in the photos hermetically sealed MIL-T-27 power transformers, MIL-approved electrolytic condensers in all power supplies, ruggedized premium-type tubes in Preamp power supplies, etc.

SANBORN COMPANY
INDUSTRIAL DIVISION
175 WYMAN STREET, WALTHAM 54, MASS.

350

Any "350" Preamplifier installs easily in any channel. Electrical connections made by mating connectors on Preamp and Power Supply.

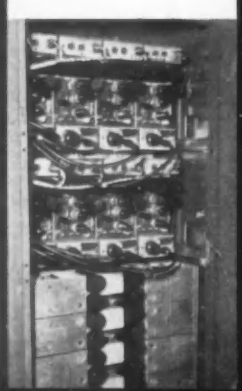


Quick, simple paper loading is done from front; hinged viewing window is removable. About 8" of record visible. All controls on front panel.

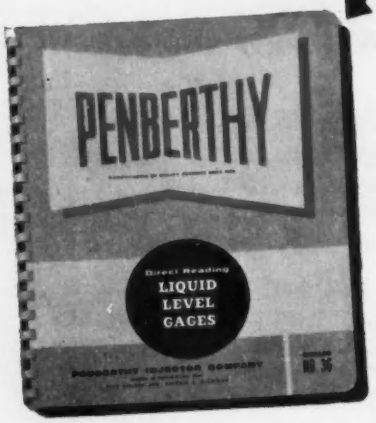
Any of nine chart speeds can be instantly selected by pushbutton. Remote control of all functions provided by connectors at rear.

Recorder back plate holds eight plug-in Power Amplifier modules (one shown unplugged in photo), four on either side of Power Supply section. Entire back plate removable for servicing.

Eight-channel "350" from rear, showing (upper half) eight individual Preamp Power Supplies on four-unit module frames, and below them, Power Amplifiers and Power Supply on rear of Recorder Assembly.



GET THIS HANDY GUIDE TO BETTER VALVES AND GAGES



Shows complete line of Penberthy valves and liquid-level gages for power, petroleum, and process industries. Includes technical data, parts, price lists, and accessories such as:

HEATING AND COOLING GAGES... for accurate readings where liquids must be cooled or heated to obtain exact measurement.

INSTRUMENT VALVE... permits gage repair or replacement without shutdowns. Back-seating stem permits repacking under pressure.

FROST PREVENTIVE GAGE... eliminates frost build-up... assures dependable visibility. For industries where frosting interferes with accurate readings.

ILLUMINATORS . . . plastic wedge distributes bright, even light along entire column. Nonglaring... dustproof for perfect illumination.

WELDING PAD GAGES . . . where process conditions require observation windows as integral part of vessel.

PENBERTHY

Dept. EN

Penberthy Manufacturing Company
Division of Buffalo-Eclipse Corporation
1242 Holden Ave., Detroit 2, Mich.
Please send FREE copy of Catalog #36.

NAME_____ TITLE_____

ADDRESS_____

COMPANY_____

FEEDBACK

Where?

To the Editor—

I would appreciate very much your telling me where I might obtain information on ac tach-compensation techniques, including ac tach-limiting.

Owen F. Dolan
Electric Boat
Groton, Conn.

There

O. F. Dolan

This is to answer your letter to the Editor regarding information on ac tachometer-limiting and -compensation techniques. Should you tell us the specific area of the problem involved, we might be in a more helpful position. However, an article, "Improve Servo Performance with Tachometer Limiting" by Robert Seinfeld, now on our research & development staff, was published in the June '57 issue of Control Engineering. This may be of interest to you.

T. N. Feng
John Oster Mfg. Co.
Racine, Wis.

Wants more on graphical analysis

To the Editor—

In the Feb. '55 issue there was an article by Prof. H. M. Paynter under the title, "How to Analyze Control Systems Graphically", which I found very interesting. Clearly many more of your readers thought so too, and later issues of your publication promised further articles. There was also an indication that Professor Paynter would shortly be publishing a book on these topics. I have watched later issues for developments, and also tried to locate the address of the Pi Square Engineering Co., where I understand Professor Paynter now is, but without success. I would be grateful for any lines of communication you can open up for me—I was impressed by his articles and would like more.

I should add that I have seen an earlier article by H. M. Paynter in "The Journal of the Boston Society of Civil Engineers", April '52, Vol. 2, in case you thought of passing this information on to me.

Charles G. Lyon
Abingdon, Berkshire,
England

Graphical analysis of control system dynamics is a subject that we cover only when we locate good material on it, not according to a schedule. Author Paynter's first CtE article on the subject, in the Feb. '55 issue, stimulated others. Perhaps you missed these in CtE:

- **PART 2, H. M. Paynter, March '55, pp. 72-78.**
- **ANALYZING CONTROL SYSTEMS GRAPHICALLY, R. H. Hillsley, Sept. '56, pp. 154-161.**
- **SOLVING FLOW CONTROL PROBLEMS GRAPHICALLY, G. A. Martin, Dec. '57, pp. 71-75.**
- **A DYNAMIC ANALYSIS KINK, Feedback, F. D. Ezekiel, Mar. '58, p. 10.**

Paynter is writing a two-volume manuscript on generalized dynamics of engineered systems. The book is, perhaps, two years away from publication. His address is Pi Square Engineering Co., Western Union Bldg., Rm. 400, Boston, Mass. Ed.

Wants ad pages perforated

To the Editor—

An idea occurred to me the other day while reading the last issue, which might be of interest to you and your advertisers. I find myself rather frequently tearing out a page from the magazine showing an advertisement on a piece of equipment which I desire to file away for future reference. It is always difficult to remove a page without destroying the binding, if I can't locate a sharp knife or shears. I wonder if it wouldn't be a reader's service and of interest to your advertisers to have all full-page advertisements slightly perforated for rapid and easy removal from the magazine.

F. L. Avera
Skippy Peanut Butter Div.
The Best Foods, Inc.
Alameda, Calif.

How about this idea? We sometimes perforate short articles that we think subscribers will want to file, but not advertisements. If we did this in an issue, perhaps it would be our "last" issue. We hope that Lee Avera means our "most recent", not "last", issue. Ed.

Paper industry can use slide rule . . .

To the Editor—

I am interested in receiving all available information on an item described in an article in the Feb. '58 issue of Control Engineering. The title of the article is "A New Slide Rule for

Transfer Functions", by J. E. Valstar, of C. F. Braun. Would it be possible for you to forward this letter to whomever could be of assistance.

E. Hypolainen
Scott Paper Co.
Chester, Pa.

. . . and so can the aircraft industry

To the Editor—

On page 135 of the Feb. '58 issue of Control Engineering Mr. J. E. Valstar of C. F. Braun & Co. described "A New Slide Rule for Transfer Functions". Would you kindly refer this inquiry for price and delivery of this slide rule to the manufacturer.

M. W. Sayler
Analog Computation & Transient Analysis Unit
Aircraft Gas Turbine Development Dept.
General Electric Co.
Cincinnati, Ohio

The author reports that he or C. F. Braun will manufacture the slide rule, but that the manufacturing plans are still indefinite. Ed.

How many watts for ball relay switch?

To the Editor—

We would like more information about the multiple ball relays described in the February issue of CtE.

Our interest is in the proximity-type limit switch shown in Figure 8. If a commercial version of this arrangement has been developed we would like drawings and descriptive matter, with prices for units capable of switching an ampere of 110 vac.

H. H. Weining
Copes-Vulcan Div.
Blaw-Knox Co.,
Erie, Pa.

The manufacturer, Congress Control Div., Tann Corp., Detroit, Mich., advises that he is preparing literature on units that will be commercially available this year.
Ed.

Corrects our Bonn news bureau

To the Editor—

Allow me kindly to rectify the following detail on page 14 of the April '58 issue of CtE:

The publications of the VDE (Verein Deutscher Ingenieure-Association of German Engineers) are the following:

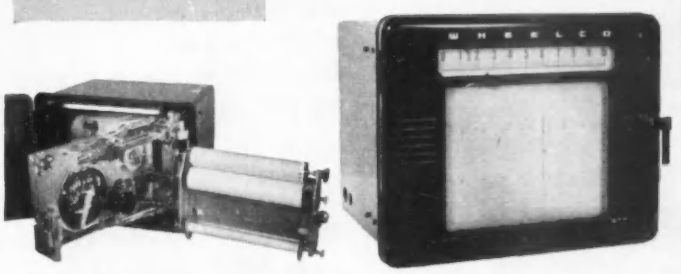
1. Zeitschrift des VDE (Journal of the VDI), appears weekly;
2. VDI-Nachrichten (VDI-News), only of minor importance, appears every alternating week;
3. VDI-Berichte (VDI-Reports), six to eight yearly, on the occasion of VDI meetings, etc.;

THE MARK OF QUALITY

BARBER COLMAN

In recorders and recording controllers ...Wheelco gives you the "extras" that really count

Wheelco Instruments



Series 8000 Recorders and Recording Controllers — available in a wide range of models, these self-contained null-balancing electronic instruments feature convenient swingout design for easy chart and instrument maintenance. Multi-point recorders keep permanent records of up to 16 points on a single chart — feature up to six limit switches for high and/or low signal indications . . . single- or multi-color printing . . . 3 to 24 in. per hr recording speeds.

Automatic Reset for Recording Controllers—available with Series 8000 instruments for demanding processes where small capacitance requires wide proportional settings and where offset cannot be tolerated. Tamperproof cover protects all adjustments, leaves necessary controls available to operator.

With Wheelco you get the flexibility of choice that makes a big difference where precision is required in process control. In automatic reset units, for example, four types are available: MP and MMP for fuel-fired installations, MMC for controlling current in electric power setups, and MMD duration-type controller for use with either system. Ask your nearby Wheelco field engineer for more details.

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BARBER-COLMAN of CANADA, Ltd., Dept. X, Toronto and Montreal, Canada

Industrial Instruments • Automatic Controls • Air Distribution Products
Aircraft Controls • Electrical Components • Small Motors • Overdoors and Operators
Molded Products • Metal Cutting Tools • Machine Tools • Textile Machinery

Giannini
PRESSURE TRANSDUCERS
for any airborne application

These instruments are typical of the extensive Giannini line of presssure transducers:

COMPACT-LIGHTWEIGHT

451218 "CUBIC INCH"

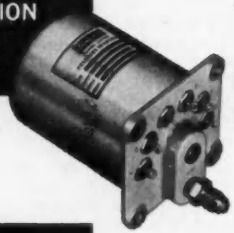
SIZE: One inch cube

WEIGHT: 2 ounces

RESOLUTION: to 300 wires (0.33%)

RANGE: 0-15 to 0-50 psi (a, d or g)

HIGH ACCURACY-RESOLUTION



451212 HIGH LEVEL OUTPUT

ACCURACY: 1% of reading for most applications (considering linearity, hysteresis and repeatability)

RESOLUTION: 2000 wires (0.05%)

RANGE: 0-10 to 0-50 psi (a, d or g)

LOW PRESSURE

45154 HIGH VIBRATION

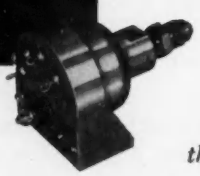
VIBRATION: 25g to 2000 cps

REPEATABILITY: 0.8%

RESOLUTION: to 250 wires (0.4%)

RANGE: 0-10, 0-15, 0-20 psi (a, d or g)

HIGH PRESSURE



461227 BOURDON TUBE

VIBRATION: 36 g to 2000 cps for special applications

RESOLUTION: to 400 wires (0.25%)

RANGE: 200-10,000 psi (a, d or g).

Detailed Bulletins are available on these transducers...write for them today.

Giannini measures & controls:

ω	β	θ	ψ	τ	ν	φ
δ	Ω,	α_t	h	P	ΔP	T
T_s	P_s	Qc	M	T_o	P_T	TAS

PRECISION INSTRUMENTS AND CONTROLS

Giannini

G. M. GIANNINI & CO., INC., 918 EAST GREEN STREET, PASADENA, CALIF.

FEEDBACK

4. VDI-Forschungshefte (VDI Research Reports).

The address is Ingenieur-Haus (Engineers' Building), Dusseldorf, 10, Western Germany.

L. A. Austrian
Consulting Engineer
Chicago, Ill.

An easier way?

TO THE EDITOR—

Surely the damping ratio for the system described in Data File No. 11 (December 1957) is more readily calculated as half the reciprocal of the amplitude when the phase lag is 90 deg, providing the overall gain is adjusted to be unity as assumed in this article.

R. S. I. Good
Edinburgh, Scotland

Offers mathematical representation . . .

TO THE EDITOR—

I read with interest the article "Electrochemical Methods for Process-Stream Analysis & Control" by T. C. Wherry and D. D. DeFord, appearing in the March 1958 issue of CtE.

I have found that processes of the type described in the article are subject to the predictive powers of mathematical analysis. Curve A, for instance, shown on page 115, may be represented by a few terms of the series:

$$I = A \cdot e^{-b \cdot \tan^2 \theta - kE^2} \qquad (1)$$

where I is the current in microamps
E is the applied voltage
e is the Naperian base 2.718.
and A, b, and k are suitable constants.

More generally, I have devised a series of the type

$$I = A \cdot e^{-a \cos^2 f(E,P)} \qquad (2)$$

which is similar to the above except that P is now an added variable (i.e., representing pressure). Equations of type 2 represent a surface on which, for instance, curves A, B, and C in the article could lie.

I would like also to point out that curves of type 1, and variations thereof, are related to the orthogonal polynominals of Laguerre and of Tchebycheff-Hermite, about which considerable literature has been published.

David Briansky
Consulting Engineer
Bronx, N. Y.

. . . Author offers more

TO THE EDITOR—

The exact equations for current-voltage curves of the type shown in

ALLIED'S MHJ RELAY
Built for Shock and Vibration

10-55 cps at 0.125 inch double-amplitude • 55-2000 cps at 20g

Here are the facts:

Contact Ratings:
Low level up to 5 amperes at 29 volts d-c or 2 amperes at 115 volts a-c non-inductive or 1 ampere inductive

Contact Arrangement:
MHJ-12D: 4 PDT
MHJ-18D: 6 PDT

Temperature:
Minus 65°C to plus 125°C

Vibration:
10-55 cps at 0.125 inch double-amplitude
55-2000 cps at 20g

Operating Shock: 100g

Weight:
MHJ-12D: 3.0 ounces
MHJ-18D: 4.2 ounces

Insulation:
1000 megohms minimum

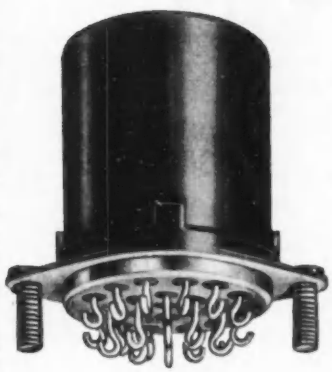
Dielectric Stress:
1000 volts rms at sea level;
500 volts rms at 70,000 feet

Initial Contact Resistance:
.03 ohms maximum at .01 to 2 amps

Operate Time:
10 milliseconds or less at rated voltage at 25°C

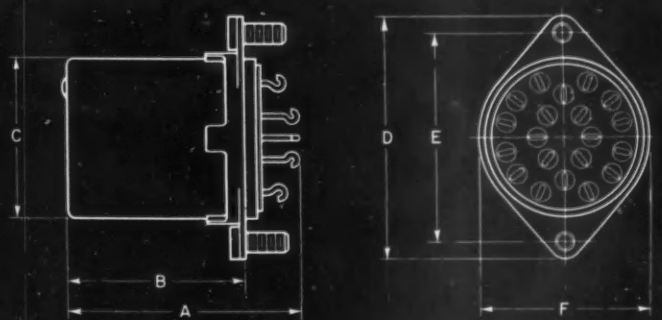
Release Time:
5 milliseconds or less at rated voltage at 25°C

Now with 5 amp Rating and Stabilized Construction*



TYPE MHJ
ACTUAL SIZE

* Includes materials and processing necessary to minimize contact resistance variations and dielectric deterioration during life due to contact contamination, mechanical wear and shift of adjustments with temperature.



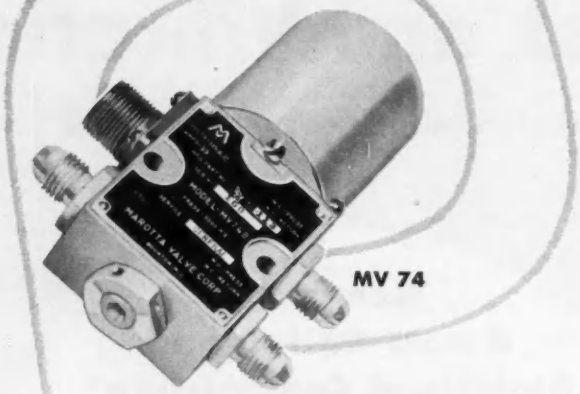
MOUNTING #6-32 NC-2A THD. (2) STUDS

	A	B	C	D	E	F
MHJ-12D (4 Pole)	1¾ max.	1 5/16	1 3/64	1 21/32	1.406	1⅛
MHJ-18D (6 Pole)	1¾ max.	1 5/16	1 3/16	1 13/16	1.562	1 5/16

ALLIED CONTROL

ALLIED CONTROL COMPANY, INC., 2 EAST END AVENUE, NEW YORK 21, N. Y.

AL 104



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JUST ONE SOLENOID VALVE WITH...

- 24 V.D.C. Power or
- 60 and 400 cycle 115 V. A.C. Power
- Fast Actuation
- Pressure ranges up to 6000 psi
- Most fluid services
- Manual overrides

for applications that require...

2 way normally closed
2 way normally open
3 way normally closed
3 way normally open
or shuttle operation

That's the versatile Marotta 3 way, 2 position, ¼ inch tube MV 74

Another addition to the over 300 Marotta valve models now in general use throughout industry.

PRV-11A Special 6" 160 psi LOX Pressure relief

RV-23 ¼" Pneumatic Regulator-Hand Type 50 to 4500 psi

MV-41A ⅛" N.C. 1000 psi Fuel Solenoid

RV-4 ⅜" 60 psi Integral Relief Pressure Regulator

MV-36 1/32" N.C. 3500 psi Internally Piloted Solenoid

write or call for complete information graduate engineers available for consultation

Marotta VALVE CORPORATION

pioneer producers of high pressure valves

P. O. BOX 330-J BOONTON, N. J.

FEEDBACK

Curve A on page 115 of the March issue depend upon the type of electrode used, the nature of the electrochemical process, and other factors. This subject has been well treated by Paul Delehay, "New Instrumental Methods in Electrochemistry", Interscience Publishers, New York, 1954. The equations for the curves obtained under many different conditions are covered in this treatise.

Donald D. DeFord
Northwestern University
Evanston, Ill.

Digger tackles tough subject

To the Editor—

A graduate in mechanical engineering from Adelaide University, I am employed by the State Electricity Undertaking. I wish to specialize in control engineering and am preparing for an ME in dynamic behavior of steam generator systems.

I shall be very grateful if you can assist me in obtaining any reviews or reports on this subject.

H. H. van Kapel
Warradale Park,
South Australia

For helpful information on such systems, we refer you to:

• BURNING FUEL TO GENERATE STEAM, T. W. Jenkins Jr., "Control Engineering", Sept. '56.

• DYNAMIC ANALYSIS OF A BOILER, K. L. Chien, E. I. Ergin, C. Ling, and Allyn Lee, ASME Paper No. 58-IRD-4.

• Forthcoming article in CtE that will describe changes in boiler design and control systems resulting from disclosures in ASME Paper No. 58-IRD-4. Ed.

Information, please—analysis, testing

To the Editor—

I would like some data regarding articles covering digital servo analysis and testing. If you have such articles for sale, I would appreciate it very much if you would send me them or the list of articles that I may purchase. Thank you.

Joseph Alferi
Garden Grove, Calif.

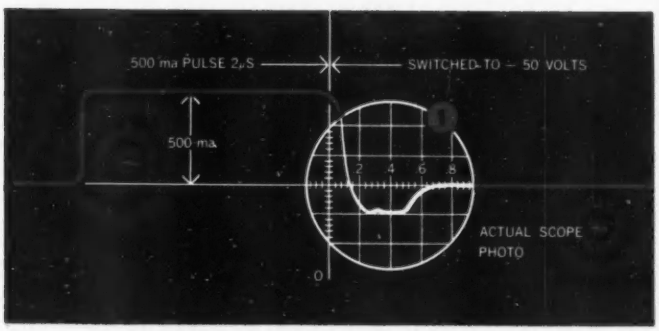
We suggest two CtE articles:

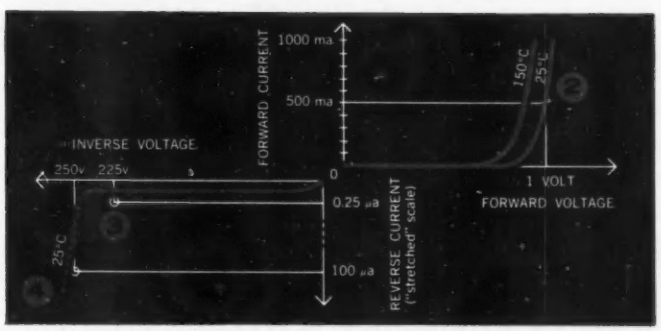
• SAMPLED-DATA FEEDBACK IMPROVES SYSTEM RESPONSE, Bertram, J. E., and Franklin, G., Sept. '55.

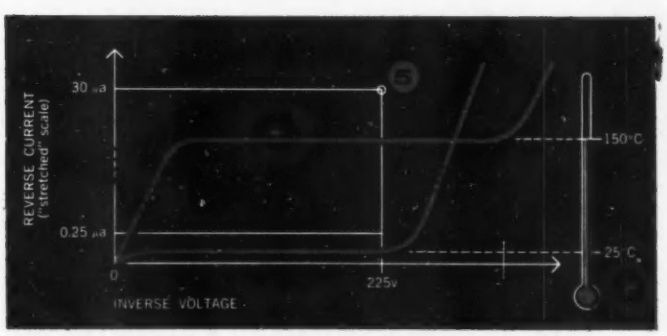
• SAMPLED DATA SYSTEMS, Gimpel, Donald J., Feb. '57. Ed.

1/2-AMPERE FAST

SWITCHING DIODE







NEW FROM SPERRY is this high-temperature S-130 series silicon diode which gives you greater current-handling capability than germanium diodes – *with no sacrifice in recovery time!*

Check for yourself the performance characteristics of this new diode in the graphs at left . . . then compare them with our *minimum* specifications below.

1. **FAST RECOVERY.** Maximum recovery time is 0.8 microseconds to return to 10 K ohms. Recovery test switches from a forward current 2 microsecond pulse of 500 ma, to a reverse voltage of –50 volts with a loop impedance of 1 K ohm.

2. **HIGH FORWARD CONDUCTANCE.** The forward current specification is 400 ma at 25° C with 1.0 volt maximum drop under static (d-c) conditions. Conductivity increases with temperature – diagram shows typical "x-y" plots at 25° and 150° C.

3. **LOW LEAKAGE** at high inverse voltage. Specification at 25° C is maximum 0.25 μa at rated voltages.

4. **HIGH INVERSE VOLTAGE.** Saturation voltages can be supplied in a range from 40 to 200 volts for this high current series.

5. **HIGH-TEMPERATURE OPERATION.** Typically, leakage current is no greater than 30 μa at working inverse voltage and 150° C. Diodes are rated for both operation and storage at temperatures from –65° to +150° C.

SPERRY SEMICONDUCTOR DIVISION
SPERRY RAND CORPORATION
South Norwalk, Connecticut

ADDRESS ALL INQUIRIES: *Marketing Department, Great Neck, N. Y., or Sperry Gyroscope offices in Brooklyn, Cleveland, Seattle, San Francisco, Los Angeles, New Orleans, Boston, Baltimore, Philadelphia.*

1948—*Early "point contact" transistor.*

The remarkable transistor observes its 10th birthday

In 1948, Bell Telephone Laboratories announced the invention of the transistor. In 1958, the transistor provided the radio voice for the first United States satellite.

To advance the transistor to its high level of usefulness, Bell Labs had solved problems which, in themselves, approached the invention of the transistor itself in scientific achievement.

First, there had to be germanium of flawless structure and unprecedented purity. This was obtained by growing large single crystals—and creating the "zone refining" technique to purify them to one harmful part in *ten billion.*

The "junction" transistor, another radical advance, spurred transistor use. Easier to design, lower in noise, higher in gain and efficiency, it became the heart of the new electronics.

An ingenious technique for diffusing a microscopically thin layer on semiconductors was created. The resulting "diffused base" transistor, a versatile broadband amplifier, made possible the wide use of transistorized circuits in telephony, FM, TV, computers and missiles.

In telephony the transistor began its career in the Direct Distance Dialing system which sends called telephone numbers from one exchange to another.

For Bell System communications, the transistor has made possible advances which would have been impossible or impractical a brief decade ago.

1958—*Satellite transistor, incorporating 10 years of Bell Labs research and development.*

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Irving Lefkowitz

switched to process control

Irv Lefkowitz was well on his way to a career as an instrument engineer at J. E. Seagram & Sons, Inc. when he heard of the unique work in process control being conducted at Case Institute of Technology under the direction of Prof. Donald P. Eckman. The intriguing potentialities of computing-control sold him. In 1953, Lefkowitz left his position as Seagram's director of instrument research, joined the Case staff as research associate and special lecturer in instrumentation.

"I had long before decided to make a career in the control field," Lefkowitz mused, "but I was wary of my educational background. One reason for going to Case was to remedy that limitation." A holder of a BS degree from the Cooper Union School of Engineering, Irv has now completed the requirements for his PhD. Last summer, he was appointed an assistant professor at Case.

During the past two years, Lefkowitz has had an opportunity to study closely one of the frontiers of process control. At Case, a research group has been hard at work filling what it considers is an essential gap between the automatic control systems of today's processing plants and the process automation concepts of tomorrow. The gap: a control system that automatically compensates for load changes and other system disturbances to meet a uniform specified quality of production at a minimum cost. This contrasts with today's most frequently used approach, in which controls maintain a constant operating condition based on fixed values. Lefkowitz has been one of the spark plugs in this program.

"We feel we can go beyond the point where the control system is set up for static or steady-state processing," says Lefkowitz. "At present, in most systems the operator is expected to change his control points to get the most out of his process. The human factor can impose some severe limitations on the design of practical processes."

To simplify the job of the human link in the automatic control chain, the Case group has called upon the high-speed analog computer, recently demonstrated the practicability of computing-control with a successful pilot-plant operation of a batch hydrogenation process (CtE, Sept. 1957, p. 197). Although the demonstration strongly implies that commercial applications of computing-control in the process industry are close at hand, Lefkowitz defends the institute's right to conduct further research along this line.

Lefkowitz's defense mirrors Lefkowitz the serious scientific researcher. He points out the fundamental aspects of the work at Case. He says, "We are trying to keep in mind the basic view of this work rather than its commercial possibilities. We would like to see the results of our work adopted commercially of course, but at present we are concentrating on general principles. We are trying to push back some frontiers. Our whole approach and objective is directed toward the development of fundamental concepts."

Based on his recent activity—lecturing and writing a number of technical papers on process instrumentation and computing control—Lefkowitz feels that development work is really just starting. As he puts it, "Work in the field of process instrumentation and control is a long way from the leveling off point. And recent world events have brought this into sharpened focus.

"As technology develops in control methods, we can see how a 'round robin' effect could evolve. New control methods will generate a demand for better processes which in turn will demand still better controls."

Teaching instrumentation and exploring the frontiers of process control leave little free time for the serious-minded, good-natured Lefkowitz. A little more than a year ago, he married a chemical laboratory technician at Western Reserve University—a rival in Cleveland's university circle. Their combined academic schedules make it tough to find time to sandwich in a few hours of concerts, theatre and discussion groups. Both Irv and wife Madelyn are devotees of the outdoor life, plan to spend vacation times traveling and camping out as a welcome relief to the academic grind.

Model of programmed steel rolling mill was displayed at English Electric booth. Here CtE's European Editor Barlow gets a close look at the model, which included tilt, and roll hole selection.

New Accent at British Instruments Show

To a visitor who attended the four previous shows, the Fifth British Instruments, Electronics & Automation Show had a distinctly new flavor. Although instruments were still widely displayed, the emphasis was now on control systems. Examples:

▶A model of a programmed steel rolling mill displayed by English Electric was the number one show stopper.

▶Numerical control systems for machine tools were exhibited by a variety of builders. New applications point to automatic testing.

▶New transistor static switching system replacing conventional plug-in philosophy stopped a lot of show visitors.

The 1958 show was the biggest to-date. During its ten-day run, over 54,000 people viewed the 90,000-sq-ft exhibit (33 percent bigger than last year). And for the first time, there was a smattering of foreign participation. This was in addition to the now traditional solid Russian contingent of 50 who are becoming a regular feature at London technical shows.

• **Systems emerge**—Last year the show was almost divided into two camps, the hardware manufacturers, who predominated, and the systems designers, primarily small companies set up for the job of fitting hardware from different sources into a complete whole. But this year the picture was different: some of the biggest hardware manufacturers said they can do systems equally as well, and as profitably.

Other show trends: Visitors noticed that communications equipment and business computer displays had disappeared from the floor. And nuclear instrumentation and control, a major factor at the 1957 show, was soft-pedaled. The emphasis centered on industrial applications. Here are some of the highlights of the 1958 show.

New gas liquid chromatograph with unusual resolution gets careful scrutiny from a visitor. Unit was offered at $2,400.

• **Heavy machinery** — Probably the eye-catcher of the show was the English Electric model of a programmed rolling mill using the BISRA translator system (CtE, Oct. '57, p. 74). The programmer is made up of plug-in function units; each can store up to 50 programs and each program can accommodate up to 15 passes.

Aiming at the same market was Metropolitan-Vickers with a system for mill screwdown control. In this system, punched tape is the storage medium; one length of tape carries up to 50 programs of screwdown settings. An experimental installation of the M-V equipment will be made this summer.

Bruce Peebles, Ltd. displayed a control system for a different kind of heavy equipment, a 17-ft-diam continuous rock tunneler. This system provides closed-loop control of drive

power to the cutting head according to cutter load, measured on a strain-gaged thrust bearing. A second loop corrects steering of the machine (which is 50 ft in length) from angular measurements.

• **Machine tool control**—Talks with a number of exhibitors made it evident that the use of three-dimensional systems for inspection is growing. For example, it was learned that the Ferranti continuous contouring system is programming a jig-borer head around an inspection piece at the government inspection establishment at Chiselhurst. Mounted in the head is a specially designed inductive probe operating a Magnagage developed by Southern Instruments. The equipment produces a chart record which indicates profiles and dimensions of work to within 10 microin.

At the Mullard, Ltd. exhibit, there was a new capacity transducer that aimed for a similar accuracy. Mullard claimed an accuracy of 0.00001 in. over a 12-in. run with a repeatability of 20 millionths of an inch.

A striking similarity was noted between two of the several point-to-point positioning systems, the electromechanical systems displayed by E. K. Cole and Airmec, Ltd. The main difference: the Ekco model (CtE, Mar. '57, p. 110) can now take punched cards as an input. (For a look at other developments on British use of numerical control, see European Report on page 29.)

• **Static switching**—In the hardware area, one of the most interesting exhibits was the Mullard transistor static switching system, which breaks away from the conventional plug-in logic unit philosophy. The system uses only four variations of basic AND/OR transistor circuits. Mullard has mounted components on printed circuit boards, each board capable of taking up to 12 logic circuits. Four of these boards are then assembled on a frame to make a page-and-book-type assembly. Mullard's approach sparked a maintenance controversy: is it more economical to replace a 12-unit board or individual plug-in logic units?

In addition, Mullard is using power transistors in the output circuits to eliminate magamps and to supply a noninductive 50 watts for actuation purposes. First installations of the new static switching boards, say Mullard representatives, will be on elevators and transfer machines.

Other static switching systems on display seemed to lack the elegance of the Mullard equipment. Metropolitan-Vickers, for example, used relatively bulky magamp timing and switching units connected in series to simulate the control and timing sequence of the process. A third system, displayed by Bruce Peebles, is still in the early stages of design. The sole application is in mining skip hoist controls.

• **Process control**—The big news in the process instrumentation field was the new high resolution NMR equipment exhibited by Fairey Aviation Co., Ltd. Composed of two small units, the Fairey NMR supplies a resolution of 1 in 10^7 from a 4-in., 4,500-gauss permanent magnet. The price: only $6,750 (less than half the cost usually associated with NMR equipment).

Other exhibitors of NMR equipment included Mullard, Metropolitan-Vickers, and Varian.

At the Pye, Ltd. of Cambridge booth, visitors could see a new gas liquid chromatograph capable of a resolution of 1,000 plates per foot (said to be three times better than competition). Pye claims that using a katharometer detector followed by a low noise dc amplifier permits a more robust recorder (10 mv instead of 1 mv), smaller sample sizes, and a bridge current of only 100 ma.

A new Dunford & Elliott displacement meter was also the center of a lot of interest. It can double as a rate-of-flow controller or a quantity meter. Its flow accuracy: 0.03 percent on any type of liquid or slurry. Stroke frequency can be reset on a timer by switches, cards, or punched tape. Cost of the valve (in size-handling rates from 20 to 20,000 lb per hour) is about $1,500.

—Derek Barlow

New transistor static switching system breaks away from conventional plug-in logic unit philosophy. Displayed by Mullard, the system logic uses only four variations of a basic AND/OR transistor circuit. Standardized printed circuit boards are capable of holding up to 12 logic circuits (foreground at left).

New low-cost, high-resolution NMR equipment consists of two units. Built by Fairey Aviation Co., Ltd., they have crystal oscillator harmonics as the rf source and a single knob tuning control.

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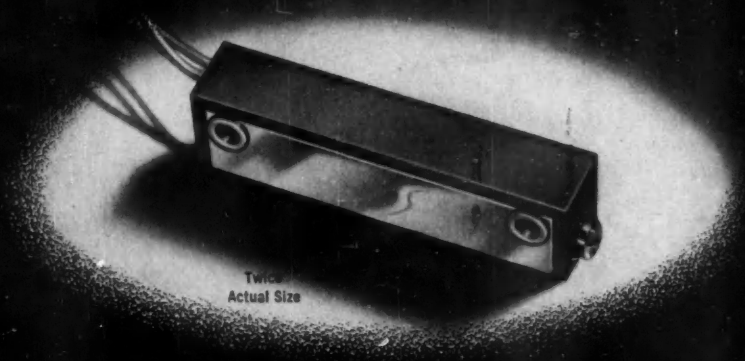

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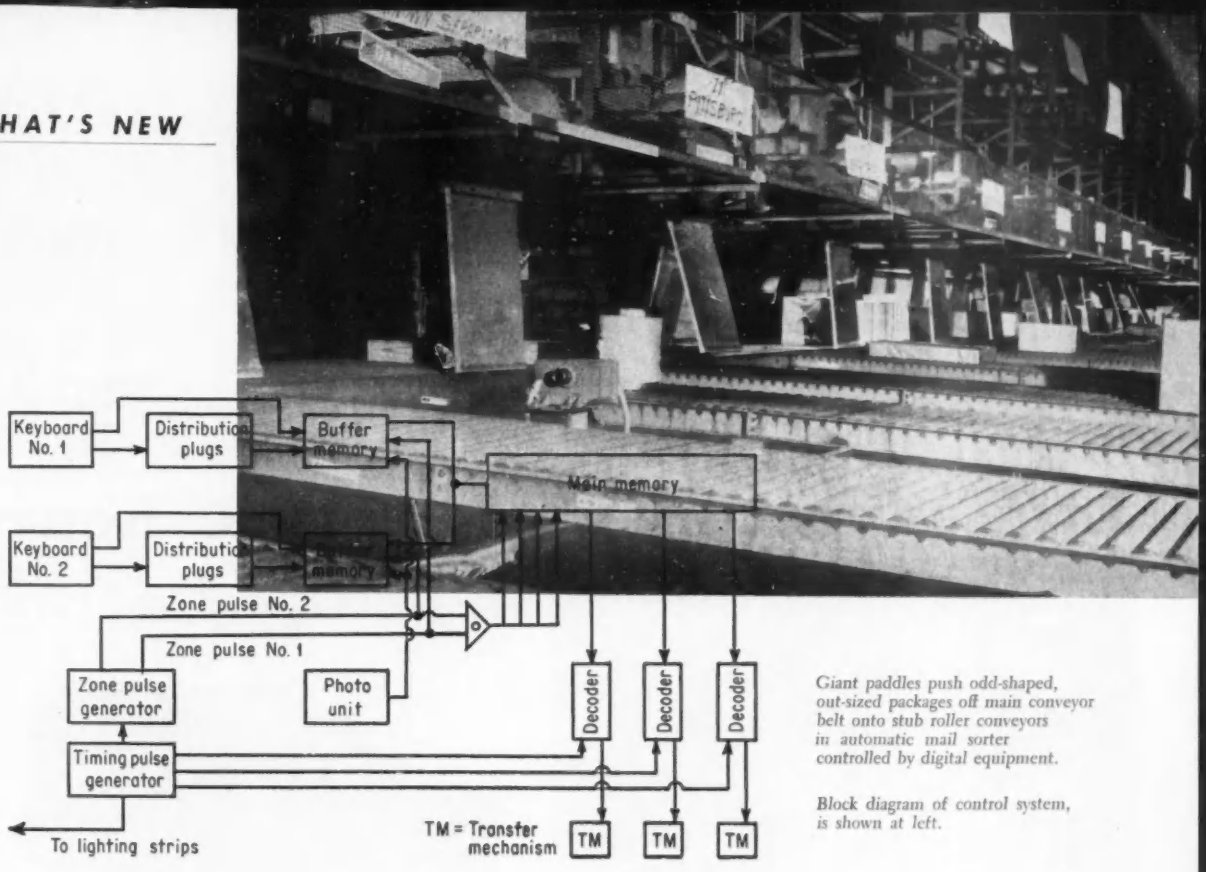

Giant paddles push odd-shaped, out-sized packages off main conveyor belt onto stub roller conveyors in automatic mail sorter controlled by digital equipment.

Block diagram of control system, is shown at left.

Mail Sorter Borrows Computer Methods

In 1955, Stewart-Warner Electronics dropped out of the radio-TV business, decided to try its hand in industrial and military electronics. In April, almost three years later, the company showed off the first tangible industrial accomplishment: an installation of an electronic package sorter at the Pennsylvania Railroad's 30th Street station in Philadelphia.

The problem solved in Philadelphia is the handling of out-size parcel post mail, that is, packages too large to go into mail sacks. The Stewart-Warner system processes "raw" mail newly arrived from the post office or unloaded from incoming trains and separates it into 39 different classifications with only a single manual handling. The equipment can sort packages weighing up to 80 lb.

To do this job, S-W employs digital techniques borrowed from computer designers. Main control components are a buffer storage unit, a transistorized shift register main memory, decoders and photoelectric cells (see schematic above). Here's how it works. A parcel, put on a moving conveyor belt manually, moves past a keyboard where a workman punches in a coded two-digit number that indicate the package's destination (the number may refer to a city, a state or a geographic area). The number goes into the buffer storage unit.

The parcel passes the photoelectric eye which reports that at a given time a package was present. This indication transfers the coded destination from the buffer storage to the transistorized shift register. As the parcel moves along the belt the coded data moves along the shift register.

As the parcel passes each unloading station, the coded information in the shift register is examined by the decoder—a large AND gate which has the coded input of the station and also an input of the proper pulse from a timing pulse generator. When the coding is correct, the decoder initiates a signal to operate the proper transfer mechanism, unloading the package.

The transfer mechanism uses servo motors to move giant "paddles" which push the package onto stub roller conveyors.

Pennsylvania Railroad's installation is currently handling about 50,000 packages a week. But S-W says this is nowhere near the capacity of the sorting system. According to a PRR spokesman, the railroad is moving out-size parcel post through its station eight to 12 hours faster with the new setup.

Cost of the installation was about $130,000. Of this, $120,000 was spent for equipment (control and stub conveyors) and the rest for building modifications to house the unit.

Stewart-Warner says it has sold several more mail sorting installations to railroads to do the same job as the PRR installation. It also has made several proposals to industrial companies which may use the control as a dispatching system for automatic warehousing. S-W and the Pennsylvania Railroad are also working on a project to adapt the system to sorting mail bags. (The major problem: fitting the required lengths of conveyors into the Pennsy's station. Said a PRR man, "This system is great if you are starting out and have to construct a new building, but sometimes it's tough to squeeze all the equipment into an old station.")

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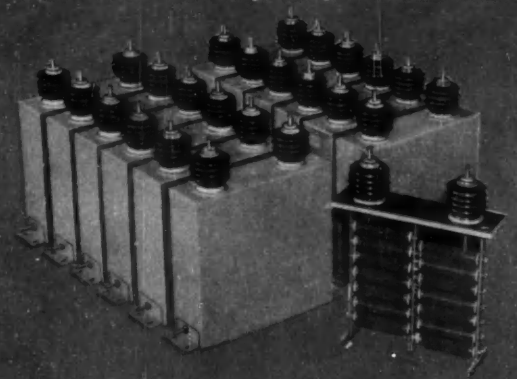

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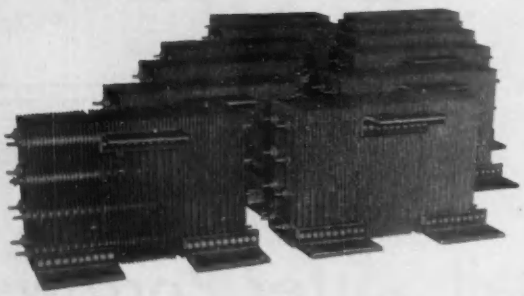

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Polaris' Fire Control

The U. S. Navy last month gave the public a peek at the proposed fire control system for its much-heralded Polaris, intermediate range ballistic missile (1,500 miles). Because of its floating launching pad, a submerged submarine, Polaris introduces some weighty problems into the firing process. Some examples: submarine motions caused by ocean currents and other turbulence; the earth's rotation; atmospheric influences.

To solve these problems the Navy will use two types of computers. One, a geo-ballistic computer, will work constantly in the submarine, plotting the location of submarine and target and considering such factors as distance traveled, motions of the submarine, and target position.

Outputs of the geo-ballistic computer will be transmitted to fire-control computers where they will be combined with additional information about the ship's motion and other influences. Then the data will be converted from analog to digital form, in which condition it will be passed to the digital computer in the Polaris guidance system. Changes in location and other launching conditions will be accounted for and corrections continuously made up until the instant of firing. After launching the inertial guidance system of the missile will take control.

The fire-control system for Polaris is being developed by the Ordnance Section of General Electric's Missile & Ordnance Systems Dept. in Pittsfield, Mass. A subcontractor of prime contractor Lockheed Missile Systems Div. GE will also produce the guidance systems, to MIT designs.

Electronic Mail Sorter Uses Conductive Ink

British Post Office has developed an automatic electronic sorting and cancelation machine. The machine takes bulk mail, differentiates between "ordinary" service (low priority) mail and "printed-rate" (high priority) mail, automatically faces the letters up, and then positions them so the stamp is in the right position for cancelation.

To make the machine work, British stamps are being printed with an electrically-conductive line of ink. Behind the development are three groups: British Government Post Office Research Team, which conceived the idea; Harrison & Sons, Ltd., printers, who developed a method of printing the stamps, and Acheson Colloids, Ltd., which developed the graphite-conducting ink.

AIA Savings in Numerical Control

For the aircraft industry, the Numerical Control Subcommittee of the Aircraft Industries Association of America keeps a close watch on what's happening in the numerical control field. Last month, the subcommittee had some striking performance information for members.

In a study of milling aircraft wing skins, records showed that the cost using numerically-controlled machine tools was $20,610, less than half the $45,040 required by conventional means. Time saving was equally impressive, AIA says: 3,249 man-hours for numerical control; 6,848 man-hours by conventional means.

Time to make another part, reported the committee, was cut from 169.66 man-hours to 7.65. An unexpected bonus: the sample part produced by the numerical controlled machine had only one dimension out of tolerance; that produced by conventional method had 12 dimensions out of tolerance.

Harwell Reactor Gets Extra Safety Instruments

As a result of lessons learned from the Windscale accident (when an air-cooled reactor spewed radioactive gas onto the English countryside), new instrumentation is being fitted to Harwell's BEPO atomic pile.

A spokesman for the United Kingdom Atomic Energy Authority said that the modifications were an extra precaution, not due to any inherent danger of BEPO. These additional instruments, mainly temperature recorders and neutron indicators, will give scientists a more accurate picture of reactor temperature conditions, permitting them to recognize dangerous situations more quickly. Insufficient instrumentation had been cited as one of the causes of the fire and resulting radiation release at the Windscale reactor.

BEPO, Britain's first large pile, was built in 1946. With a full power output of 5,000 kw, its prime function is to produce radioisotopes.

Army to Build Computing Command Post

In the future, Army field commanders will use the last word in automatic data processing techniques to plan ground maneuvers. U. S. Army has awarded a $6,851,000 contract to Aeroneutronic Systems, Inc. to develop a mobile electronic command post. Called the Tactical Army Operations Center, the equipment will permit field commanders to exercise faster control over dispersed units.

All equipment of the command post will be mounted in vans. Included in the proposal: a computer complex, data processing and visual display equipment.

Foreign Translations Expressed

International Physical Index will soon start publishing a series of scientific periodicals based on translations from 67 current Russian technical periodicals and transactions. Each IPI periodical, called an express service, will consist of complete articles, excerpts and abstracts, annotated titles and topical bibliographies. The three expresses: 1) electronics, 2) automation, and 3) physics.

There are nine major subdivisions in the electronics express. Of primary interest in the control field are: research and control instrumentation, solid state devices, and circuits.

Practically all subdivisions of the automation express are in the control field. They include: information theory, digital and analog computers, control systems and data handling, servomechanisms, and magnetic amplifiers.

Each express issue will contain 40 pages, and will appear 10 times per year. In a single issue, there will be two to four complete articles, 10 to 20 excerpts, 30 to 50 abstracts and as many as 100 annotated titles.

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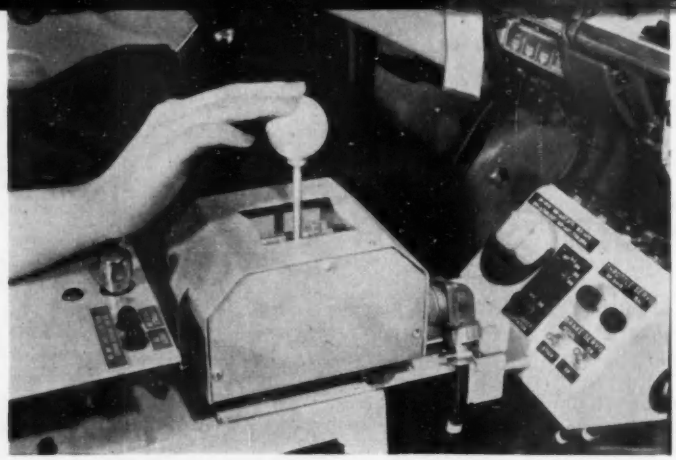

Stick topped by heavy ball replaces steering wheel, accelerator, and brake pedal in General Motors' new Unicontrol, an electrohydraulic system.

Automakers Study New Car Control Systems

To Detroit automakers, one of the biggest problems is coming up with something new every year for potential car buyers. One development being heavily pressed for possible introduction sometime in the future is automatic car control. In April the visit of the Governor's Committee for Highway Safety gave automakers an excuse to show off what they've been doing and thinking about in new car controls.

General Motors took the wraps off its "Unicontrol" (photo above), a system that replaces the steering wheel, brake, and accelerator with a four-inch stick, topped by a heavy ball. Ford demonstrated a tiller-bar control systems.

In Unicontrol, the control stick can move 2 in. in any direction from center. To steer, the driver pushes the stick to right or left. Pushing the stick forward accelerates the car; pulling it back applies the brake. Steering and motion can be coordinated in a single motion.

The driver exerts only 1 lb of pressure to move the spring-centered stick, which is damped to prevent oscillation or wobbling when released. Steering ratio is varied with car speed to reduce the possibility of skids caused by abrupt movement of the control stick.

Between the control stick and steering mechanism, throttle, and brakes are an electronic computer and a hydraulic power supply. GM is using the same equipment in the Unicontrol car and in its automatically controlled electronic Chevrolet (CtE, Mar. '57, p. 26). In fact, the Unicontrol car is also equipped for automatic guidance by low frequency ac power carried in a wire buried in the pavement.

To make a turn, a signal from the control stick is sent to the computer, which computes proper wheel angle using this signal and car speed, then sends an output signal to a hydraulic servo. It's the servo that positions the wheels. Brake and accelerator controls are also servo-actuated.

Certain "road feel" characteristics have been built into the system. For example, the inertia of the heavy knob indicates the motion required to correct a skid. Inherent pendulum stability in the stick minimizes the buffeting effects of wind gusts and road irregularities.

According to GM researcher Joseph B. Bidwell, Unicontrol is one phase of a long-range control study. A major objective: to determine what controls suit drivers best, regardless of how drastic such systems might be.

Answering questions about driver

Tiller bar control is used by Ford Motor Co. in experimental car instead of steering wheel. Ford's study is being made to determine whether to abandon conventional controls.

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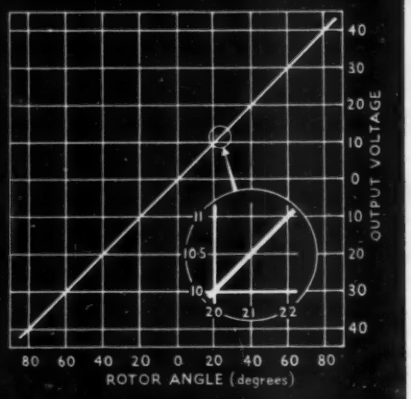

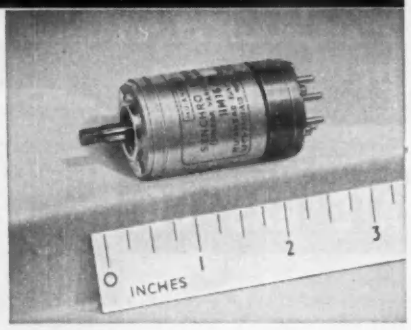

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SUPPLY FREQUENCY	400c/s
POWER CONSUMPTION	0·40W
MAXIMUM OUTPUT VOLTAGE	42·5V
VOLTAGE GRADIENT	0·5V per degree
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RANGE OF LINEARITY	±85 degrees
ACCURACY	±1/4% of maximum voltage
WEIGHT	4·5 oz.

Delivery, prices and a data sheet giving full information on the Size 11 Linvar are available on request.

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WHAT'S NEW

training, Bidwell claimed that Unicontrol had proved easy to use. Over 100 drivers have tried it, he said. And they all could drive passably with the system after a few blocks, reached competence after a few miles.

• **Ford's approach**—Meanwhile, at Ford Motor Co. researchers have been studying a less elaborate system. More an effort in human engineering than in control design, the Ford system also uses electrohydraulic gear to control steering. Ford engineer Henry Mika explains his company's approach: "The problems of a unified control system (such as GM's Unicontrol) are more psychological than technical. We can't throw too much complication at the driver all at once.

"We are studying steering now," he adds, "to find out whether there is an advantage in abandoning conventional car control systems."

Ford is experimenting with a hand control similar to the "joy stick" of aircraft. Right or left motion of the stick creates an error signal between a potentiometer on the stick and a slave on the pitman arm of the steering linkage. After being amplified, the signal powers a torque motor to move a spool in a hydraulic valve. This valve controls the hydraulic mechanism that moves the front wheels.

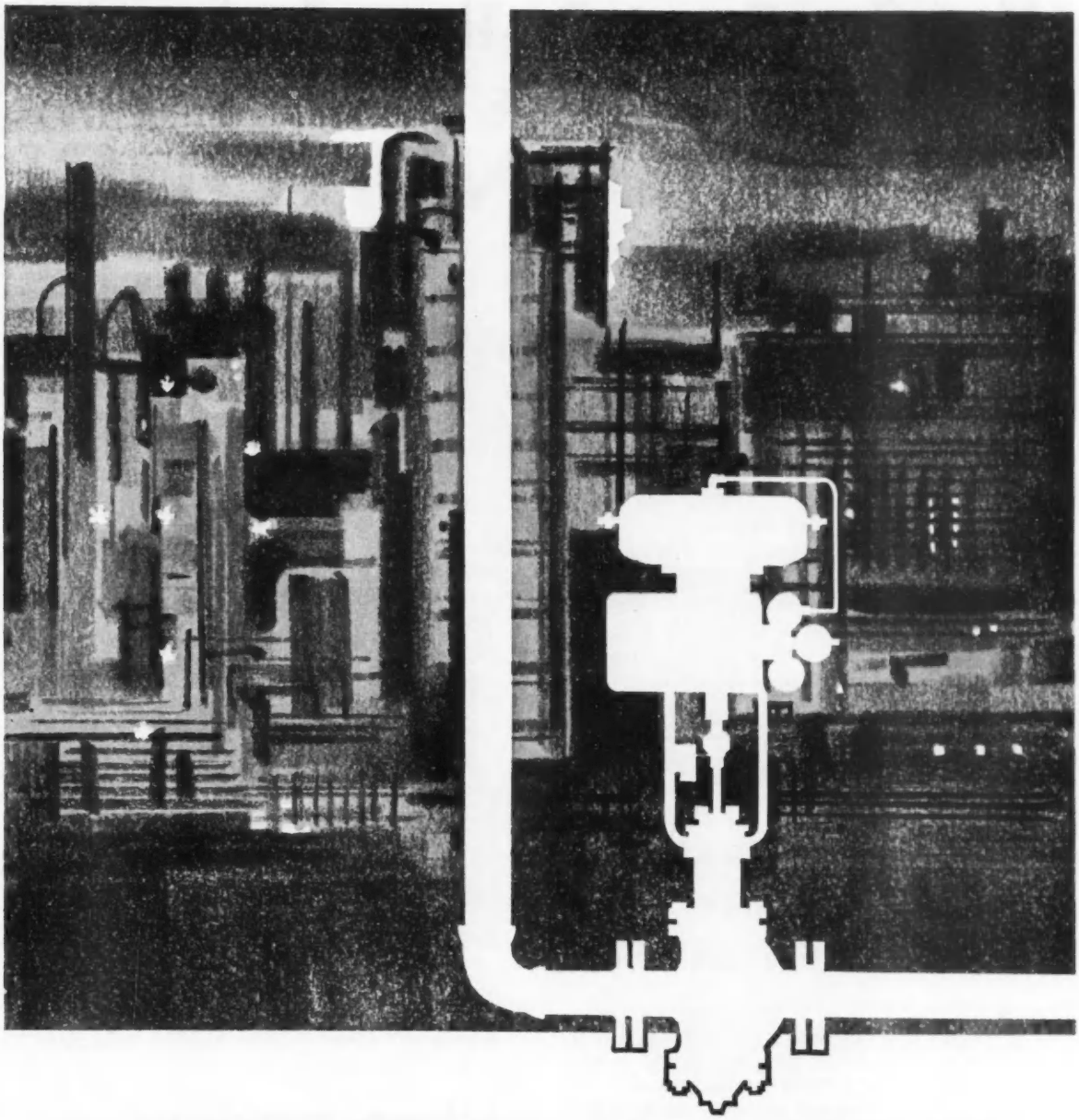
—Donald MacDonald
McGraw-Hill News

Gordon Conferences

Three New England schools will again host the summer Gordon Research Conferences, established to stimulate research in universities, foundations, and industrial laboratories.

The 36 one-week meetings (each meeting covers a different area) will be divided between Colby Junior College in New London, New Hampton School, New Hampton, N. H., and Kimball Union Academy, Meriden, N. H. Subjects at meetings cover a wide variety of industry fields (petroleum and textiles) as well as sciences. The program on instrumentation, scheduled for July 28 to Aug. 1, includes these invited papers: Image tubes and their Astronomical Applications by William A. Baum; Automatic Data Logging by Philip G. Gilman; Masers by C. Lester Hogan; and Solions by R. N. Lane.

Applications for attendance at any of the Gordon conferences should be addressed to W. George Parks, Director, Dept. of Chemistry, University of Rhode Island, Kingston, R. I.



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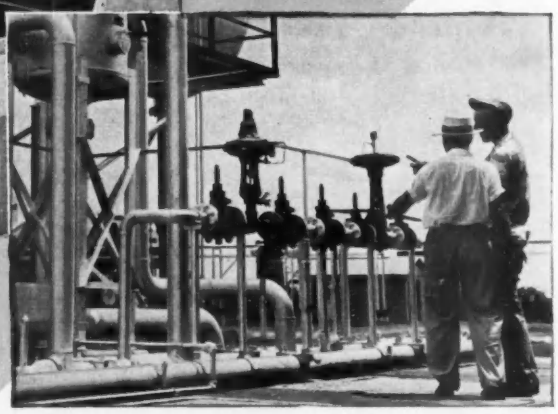

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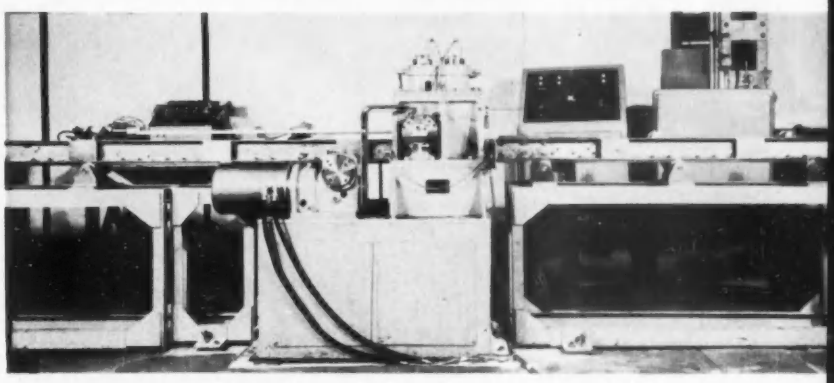
Numerical Control Grows and Grows

British interest in numerical control of machine tools is increasing. English companies are quietly stepping up their investment in numerical control developments. Some outstanding evidence:

- Ferranti, Ltd., usually acknowledged as one of the leaders in the field, has six systems in use, has orders for 12 more.
- Vickers-Armstrongs (Aircraft), Ltd. is concentrating on point-to-point systems. Vickers has developed two positioning systems and a programmed pipe bender.
- EMI, which has developed an analog system, is now working on a point-to-point system.
- Five of Britain's nine major aircraft companies have numerical controlled machine tools installed, mostly on production jobs.



Vickers' stringer piercing machine uses counting unit (left of piercing assembly) to actuate four prepositioned electro-pneumatic heads.

Numerical control development has been stimulated by Britain's $862.2 million aircraft industry, just as aviation companies pushed U. S. developments. But developments of numerical control systems in the United Kingdom is only very occasionally government-financed. In such cases the Ministry of Supply, a coordinating body between the three services and industry, places the contracts while keeping a close check on any developments privately sponsored by individual firms.

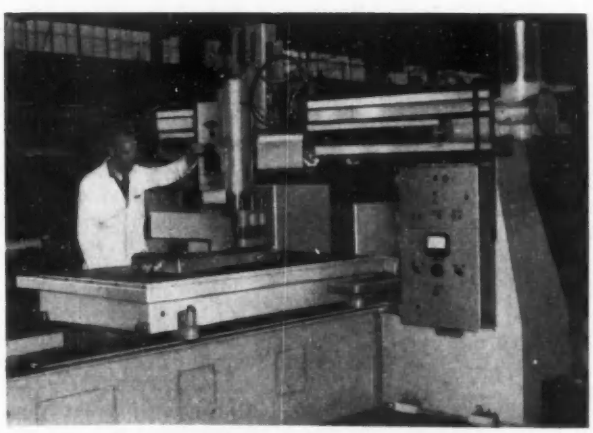
This is in marked contrast with the coordinated backing that the USAF Air Material Command has put into continuous contouring. Nevertheless, Britain's aircraft industry has been steadily increasing its investment in numerical control techniques.

In the continuous contouring field, Ferranti, Ltd. is Britain's acknowledged leader. The latest installation — developed in conjunction with Fairey Aviation—is on Western Europe's largest profile miller.

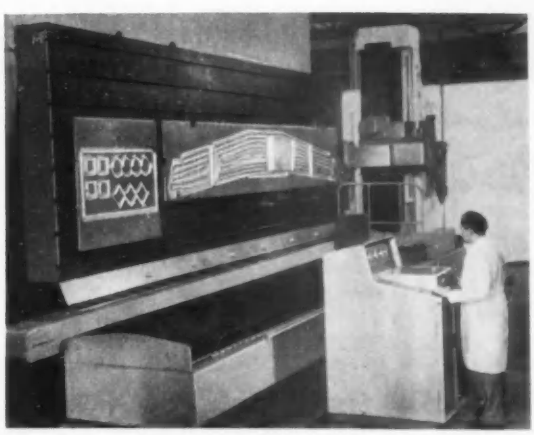
The equipment has a number of firsts. For example, it is the first machine to be designed in Britain as an integral part of the control system. It's machining accuracy of 0.002 in. is said to be higher than any other.

The three-dimensional machine has novel bearing ways, developed as part of the integrated design to match the machine dynamics to the control system. Its column floats on a thin oil maintained at pressure, between the top and bottom surfaces of the nitrated-steel ways. This completely removes stiction and breakaway effects when the column is moved from rest. Fairey designers say that in the initial tests a 1-lb weight suspended over a pulley moved the 9-ton column from rest to a speed of 5 in. per min.

Positional information is derived by 500-line-per-inch diffraction gratings. A specially designed hydraulic system increases the response to better than 3.2 in. per sec. Response is limited not by the servos but by the central computer and tape packing. Since each digit corresponds to 0.001 in. of table movement, computer outputs of more than 3,200 digits per sec are required, a volume which rapidly approaches the permissible



Vickers' coordinate positioning drilling machine uses stepping relays and dekatron counters to give positional accuracy of 0.001 in.



Fairey's new skin miller is first British machine tool designed as an integral part of the control system.

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This machine is currently undergoing acceptance trials for the Ministry of Supply, which is footing its estimated $240,000 cost. If it wins approval, it may be the forerunner of four- and five-axis machines.

• **Vickers' entries**—A new contender for the numerical control laurels is Vickers-Armstrongs (Aircraft) Ltd., of Weybridge. Details released in a recent paper by L. G. Burnard, assistant to the general manager of one of the Vickers plants, show a prime concentration on point-to-point systems. Privately-sponsored, these developments include two positioning systems, a programmed piercer and lofting machine, and work on a programmed pipe bender.

On a production drilling machine, the Vickers coordinate positioning system obtains its positional information photoelectrically from discs mounted on the recirculating ball nut leadscrews in the X and Y axes. Standard five-channel teleprinter tape is used for coding the coordinates, with each channel representing one decade. The number in each decade is represented by the number of holes punched longitudinally in the tape. The position information is first stored on a bank of stepping relays, which move to an analog of the coordinate number. From the relays the ordinate numbers are transferred to a dekatron counter.

A self-checking system is provided by a second tape punched with the complement of the position information. This is stored on stepping relays and transferred to a second dekatron counter.

Basically the same system is used in the Vickers stringer piercing machine. The drilling program on the punched tape advances the stringer through the piercing head, where four pneumatically operated punches in preset positions pierce the holes in their correct location. The 62-ft length of stringer is advanced by a rack and pinion system drive, from which a photoelectric count is obtained. The tape carries, in addition to the position requirement, the punching instructions for the electro-pneumatic piercers.

Another example of Vickers activity is its template lofting machine. Here the coordinates are set in on rotary switches and as the machine traverses, it makes the templates and lays out loft lines. In addition to template

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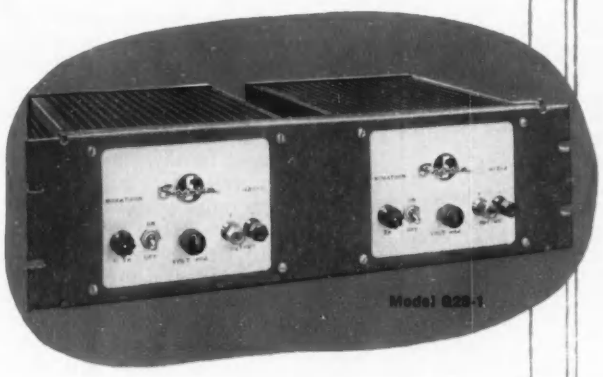

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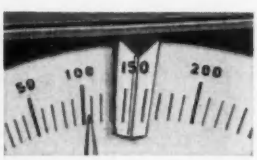

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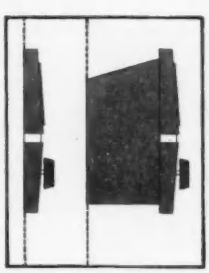

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WHAT'S NEW

layout, grid ruling and curve interpolation are possible. An optical system projects a pair of cross-lines on the curve, and by reading off the coordinates clocked up in dekatron counters, empirically generated curves can be measured.

Completing the Vickers quartet is a programmed pipe bender, still under development. Here the pipe is extruded first through a fixed die and then through a movable die. By controlling the displacement of the movable die, bend in any direction and of any curvature can be generated. At present, a series of cams mounted on a countershaft linked with the die motion control the amount of bend. A second cam system controls the rotation of the collet in which the pipe is mounted so as to give the correct angular relationship between bends.

Vickers wants to replace both cam systems with simple numerical control so that setting up will be reduced to inserting the appropriate diameter dies and collects. The tape will then provide dimensional information on bend position, radius, and direction.

Other coordinate position systems are available for British industry, too. Most notable are those of British Thomson-Houston Co. (CtE, Jan., p. 78), Ekco Electronics, Ltd. (CtE, March, p. 40) and EMI, Ltd. of Hayes. One of the first British contributions in continuous contouring, the EMI system—basically analog with transformer taps providing parabolic interpolation—will soon be seen in the United States, as a result of the development agreement just signed with Cincinnati Milling Machine Co.

In recent months, EMI has expanded its activity towards point-to-point. The Atlantic drilling machine manufactured by Industrial Technics of Southampton incorporates the EMI system, using for its pick-off device the Farrand Inductosyn.

A round-up of British aircraft firms shows that of the nine major companies, five—Rolls-Royce, De Havilland, Bristol, Fairey Aviation, and Vickers-Armstrongs—have numerical control systems installed mostly on production jobs. With system types fewer than in the United States, less evaluation time is required before purchase, a fact that may accelerate Britain's cautious start. No one doubts the advantage of numerical control, but the big question is how much and how fast to invest, particularly when the money has to come from the company's own capital spending program.

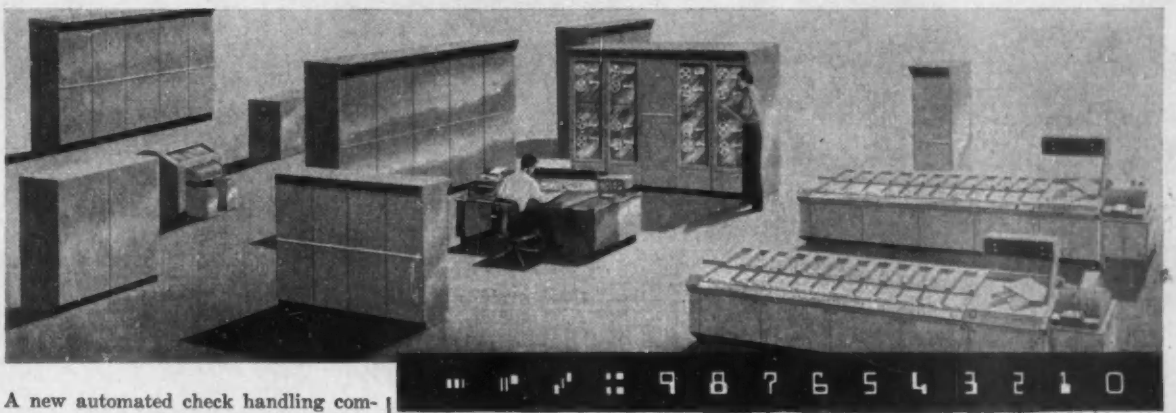
—Derek Barlow

COMPUTER PROGRESS

Digital and Analog Computers at Work

ARTICLE 1 VOLUME 1

MAGNETIC INK CHARACTER READING COMPUTER SYSTEM TO SPEED BANK CHECK HANDLING WITH INCREASED ACCURACY



A new automated check handling computer system is being manufactured by the General Electric Company Computer Department for today's modern banks.

One of the unique features of the system is a magnetic ink character reader which actually "reads" the Arabic numerals illustrated above, and thereby eliminates the need for punched cards or tape as input to the system. The check itself is fed into the computer.

Basically, the technique is simple. Account numbers are preprinted on customers' checks in magnetic ink. When the check is turned over to the bank, the dollar amount is imprinted on it, also in magnetic ink. From there on, the data processor handles all the mathematics involved in determining if there are sufficient funds, and if there are holds or stops against the check. Then it computes the new balance, and finally, it issues the monthly statement.

The General Electric system offers a high degree of speed and accuracy, easy verification, no radical check format changes, relative invulnerability of encoded data to obliteration, low costs. Customer acceptance is virtually assured.

Because the system agrees with an American Bankers Association committee recommendation, a high degree of system acceptance with leading banks and financial institutions is assured.

COMPUTING SERVICES GROUP HANDLES COMPLEX ORIGIN-DESTINATION STUDY FOR WESTERN CITY

The Computing Services section of the G-E Computer Department recently completed an origin-destination tabulation for the Phoenix-Maricopa County Traffic Study Group in Phoenix, Arizona. The results of this tabulation, when analyzed, will enable the group to plan the street and highway development program of this desert metropolis for years to come.

The original survey information was obtained by the city-county personnel using the interviewing procedures set up by the U. S. Bureau of Public Roads. The data was put on punched cards and then turned over to G-E for processing and tabulation.

Using manual, or simple computing methods, such tabulations often take many months—sometimes years—to complete. However, using General Electric's giant computer on a rental basis, the job was completed in just a few weeks. The Computer Department also performed the difficult programming job.

(Programming, simply stated, is the translation of the solution method into the language a computer can understand, and the issuance of instructions to the computer so that it will process the information as it is fed.)

The Computing Services section of G-E's Computer Department is staffed with 125 analysts, programmers, coders —all leaders in the computer field. Their services are available, along with time on the large and versatile IBM 704 computer, to handle the problems of industry, business, government and education.

NEW TRANSISTORIZED CHARACTER READER ANNOUNCED

A fully transistorized magnetic ink character reader has been developed by the General Electric Company Computer Department at its research laboratory in Palo Alto, California. The reader will be used as part of G-E's data processing system for banks, but other applications are being studied.

The new character reader is about the size of a typewriter, and does the same job as a vacuum tube version that is four times larger. Solid state circuitry throughout requires less power, cooling and delicate handling than was required for the vacuum tube model.

For more information, please contact: Computer Department—Room 227, General Electric Company, 1103 North Central Avenue, Phoenix, Arizona.

CPA—6

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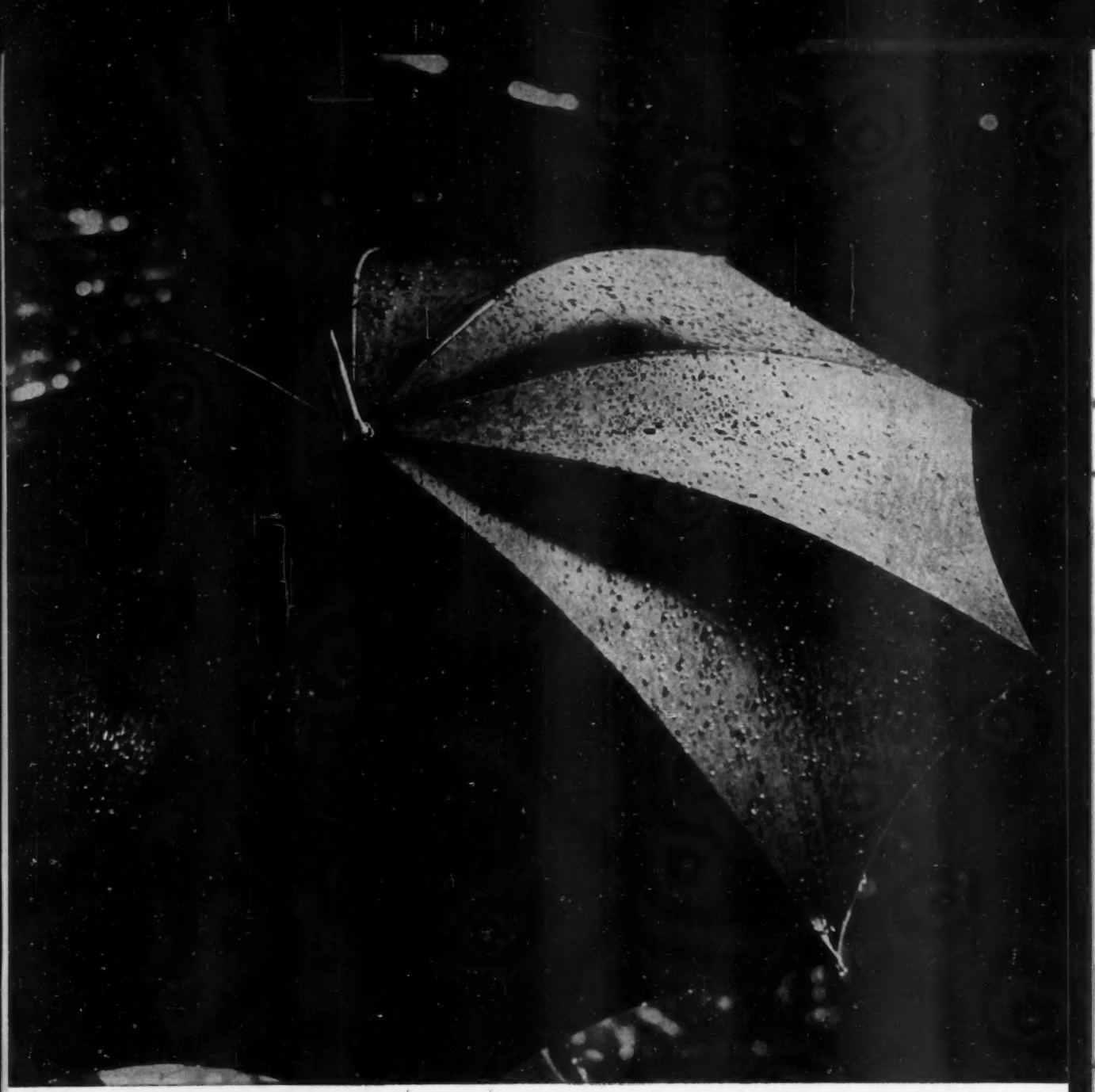

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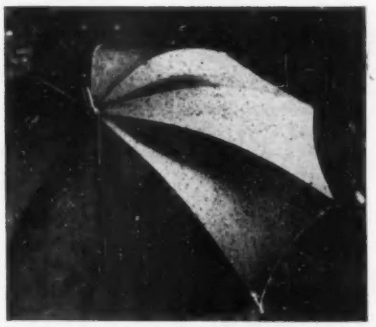

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A Hard Look at Production Control

Use of electronic computers in production control was the chief topic of a recent ASME meeting. But potential users are going slow, looking at the economics.

Factory engineers in metalworking are taking a close, hard look before applying electronic computers to production and inventory control. Nobody's going overboard. A day's discussions on the subject at a conference sponsored by the Production Engineering Div. of ASME at Worcester, Mass. in April indicated that production men want to see economic justification for such equipment first.

The lure of computers on the program was strong enough to draw attendees from as far away as Illinois. Almost from the start, the audience exhibited a "show-me" attitude on computer applications.

James E. Haynes, IBM, discussed how his company used an IBM 650 to control production and inventory. He cited added speed and accuracy as the main advantages. One specific improvement: a division could run an inventory report on 20,000 parts in 1½ hours instead of the two months required by punched card techniques. The first questions fired at Haynes after his presentation: "Did the computer pay for itself? What were the economics?" Haynes had to reply that, as yet, IBM had no dollar figures to justify the computer. Another visitor asked Haynes to define general criteria for economic justification. To this, Haynes answered that there are no general rules; each application requires its own study.

Another IBM speaker was grilled hotly too. William R. Elmendorf presented a proposed data processing system to control a job shop machine floor with a RAMAC stored program computer. He listed four objectives of the system: 1) to install in-line data-processing, 2) to permit prompt and effective analysis, 3) to insure up-to-date scheduling, and 4) to improve accuracy of data processing. Elmendorf's program offered a bonus: simulation of machine loads to help management try out alternate loadings.

But questions from the floor indicated an unenthusiastic reception. Typical posers: What are the economics associated with this system? How can such a complicated system be applied to a small job shop? How can a job shop with custom-style production gather the large amounts of historical data required? And to these there were no easy answers.

More to the audience's liking was a paper presented by W. Bruce Pirnie Jr. of The Jones & Lamson Machine Co. Pirnie reported how his company was using tabulating equipment (an IBM 604 punched card programmed data processing system) already at the plant for accounting purposes to handle production control. The equipment was doing a job that clerks have been unable to handle because of the large volume of transactions. The major advantage: fast and accurate preparation, weekly of production reports and machine loadings.

Arthur Maynard, General Electric Co., perhaps best expressed the tone of the conference. Suggested automation specialist Maynard, "A good systems analysis will usually pay for itself in savings. One of the first questions to be answered is 'Can our data processing be automated?' Then, 'Should our data processing be automated?'" It was Maynard's contention that systems analysis would point out whether or not a computer was justified in production and inventory control. Another thought-provoking idea offered by the GE engineer was that the majority of computer applications have been made by "fitting the system to the machine (because of the availability of the machine), not of fitting the machine to the system".

In off-the-floor discussions, a systems engineer at a large jet-engine plant said that his company was trying a computer for production control. The main reason: to get experience with the system because the company feels it will have to have such equipment to be competitive five years from now. A manager of systems at a large steam turbine builder looked at economic justification this way. Said he, "How 'sloppy' your present production control system is determines to a great extent how much you could afford to pay for an improvement

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WHAT'S NEW

with a computer. If the system is real bad, you could save enough to justify a very expensive computer. But there are some production control systems that are so efficient with manual labor that I doubt if you could ever save enough money to replace them by computers."

—Lewis H. Young

Southwest Builds on Oil, Aircraft, and Missiles

SAN ANTONIO—

The present and future of Southwestern control manufacturers are built around the oil industry—with its concentration of refineries and petrochemical plants along the Texas Gulf coast, the aircraft industry in the Fort Worth-Dallas area, and the missile, rocket, and atomic energy industry of New Mexico. This three-way interest was reflected in the talk and displays of exhibitors at the 10th annual Southwestern IRE Conference and Electronics Show in April.

Although attendance at the show was somewhat disappointing (said one exhibitor, "San Antonio's a tough place to get to") indications were evident that area control companies are taking dead aim at the local industrial concentration.

The Southwest has long held a stranglehold on geophysical instrumentation. But companies here have barely dented other areas such as process instrumentation and test gear. Now the picture is changing.

Research in the area is getting a big boost from several directions. There is expansion among some of the best known organizations, like Southwest Research Institute and Texas Instruments (which chalked up a record-breaking first quarter sales and net in 1958 after a record-breaking year in 1957). TI has moved into guidance systems for missiles.

Another important nucleus of research is southwestern colleges. At Austin, Tex., for example, three research laboratories—the Defense Research Laboratory, the Electrical Engineering Research Laboratory, and the Military Research Laboratory — have spawned several new companies.

Typical of area interest in process control is the analog computer being built by Southwestern Industrial Electronics Co. for Humble Oil. Humble will use the computer on a fractionation tower to calculate vapor efficiency.

—Kemp Anderson
McGraw-Hill News

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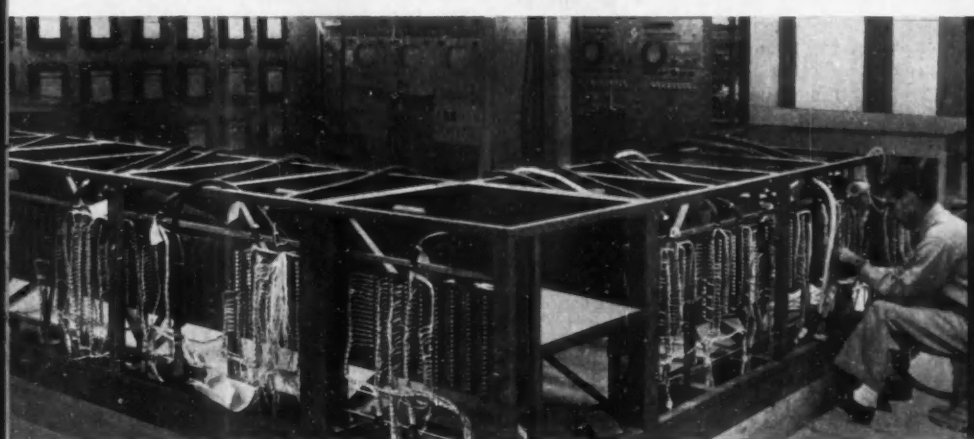

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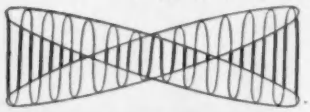

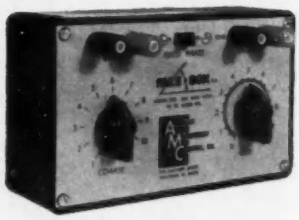

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AROUND THE BUSINESS LOOP

Gathering for Upswing

Last month, faster than a typesetter's wink, business took another notch in its belt. But undaunted economists continue to see signs of improvement. Here are some examples relating to control.

For the past 11 years the McGraw-Hill Dept. of Economics has been looking at and reporting on plans by business for new plants and equipment. In this same 11 years the Scientific, Motion Picture & Photographic Div. of the Dept. of Commerce's Business & Defense Services Administration has been following trends in the scientific and industrial instrument industry. Together, the latest reports by both groups of observers put the economy, as it affects the control field, in the brightest light in months.

Most encouraging are reports from the electrical machinery, aircraft equipment, chemical, and petroleum and public utilities industries, on their spending plans for 1958. All have to do with control engineering in one respect or another, and all say they will spend the same in 1958 as in 1957, or more.

• **Evidence**—Here are some specifics. Electrical machinery: 4 percent increase anticipated in 1958, still more in the three years to follow; aircraft equipment: a revision upward to within 3 percent of the 1957 level; chemicals: a relatively high level of spending—$1.6 billion in 1958 and $1.3 billion in each of the next three years—making this industry the leader in size of capital expenditures; and petroleum and public utilities: a substantial increase in plant and equipment expenditures in 1958.

Another barometer of economic conditions is planned outlays for research and development, and here, too, the signs are favorable. Of course, several control companies have scheduled big R&D expenditures despite the recession (CtE, May, p. 172), but these cannot possibly account for the nearly 60 percent of all manufacturing companies that McGraw-Hill reports are now working on new products or processes. Says McGraw-Hill: 12 percent of sales (the highest ever reported) has been earmarked for R&D in 1961, compared to the 10 percent expected to be applied to this area in 1960.

• **Consistent increase**—Expenditures for R&D, it is said, reached a record $7.3 billion last year—just about in line with a 20-percent planned increase forecast a year ago. And this year plans call for $8.3 billion in R&D spending, or 14 percent more.

Partially reflected in projected R & D outlays are what the respective companies expect to make in sales, and here there is still further reason for smiles. "Companies surveyed expect 1958 to be a lower sales year than 1957, as a whole," McGraw-Hill says. "However, they also seem to expect some upturn in sales before 1958 is over." And: "Manufacturing companies, as a group, plan to increase unit sales volume 20 percent from 1958 to 1961. This is important in two respects. First, it shows clearly that industry is not figuring on a long slump in the economy. Second, it indicates plans for solving the problem of excess capacity."

The Dept. of Commerce seems to share this view. Its feeling about the immediate future for scientific and industrial instruments: "During the first half of 1958 (they) will maintain the same annual rate of sales prevailing in 1957—approximately $3 billion. In the second half of 1958, the annual rate is expected to rise sufficiently to bring the year's sales to about $3.25 billion."

• **No panic**—According to McGraw-Hill, industry as a whole is "not figuring on a long slump in the economy". Its level of spending for 1959-1961, averaging $30.5 billion a year, is well above the $22 billion indicated when it was cutting down to a minimum, a clear sign that panic and fear of a business depression are not components of anybody's thinking.

And as far as the slump itself goes, it could have definite purging effects; that is, it could, says McGraw-Hill, trigger "the most rapid replacement of obsolete equipment, and the greatest emphasis on cost-cutting improvements since the years just after World War II", simply by causing a shift of capital investment from plant expansion to plant modernization. The reason would have to be tied, to

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More to come

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- Internal Parts—Stainless steel—give long, trouble-free service
- Coil—Continuous duty—10 watts max.—UL-approved
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- Mounting—Direct-line—can be serviced without removal from the line
- Options—Explosionproof, Manual Override, Electrical

SKINNER'S NEW 2-WAY VALVE OFFERS

big capacity — high pressure

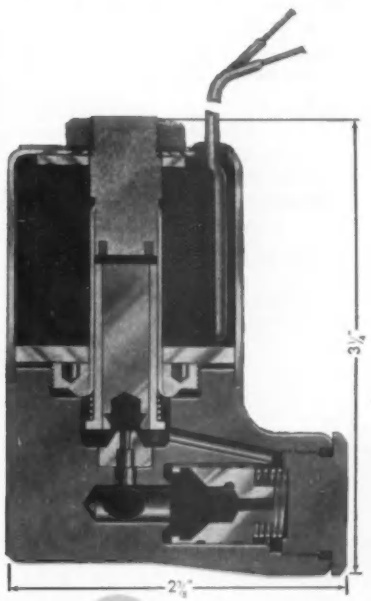
Here's the second new line of valves designed to answer your control "puzzles." This new line, called the R Series, is a two-way, pilot-operated piston valve with ¼" orifice and ¼" NPT. It is available normally open or normally closed and operates on a pressure differential of 5 to 200 PSI. This new R Series also includes an Explosionproof line in normally open and normally closed construction. A normally closed version will be available soon to operate on pressures up to 1000 PSI.

This new R Series uses the famous Skinner V5 Operator and will control air, water, oil and semi-corrosive media. The normally open version can, on request, be supplied with pilot exhaust piped to body outlet port.

A wide selection of coils—high-temperature, waterproof and standard—for common AC and DC voltages is available, and there is choice of electrical connections such as Automotive Terminals, Grommet and Conduit.

The temperature range of this new line is −65° to 180°F Ambient, and −65° to 150°F Media. It is light in weight—only 1¼ pounds—and can be mounted directly to the line by means of the ¼" NPT. Distance between ports is 2 inches.

For complete information about this new line of Skinner valves, please contact our Representative or Distributor near you—you'll find him listed in the Yellow Pages. Or write us at the address below, Dept. 346.



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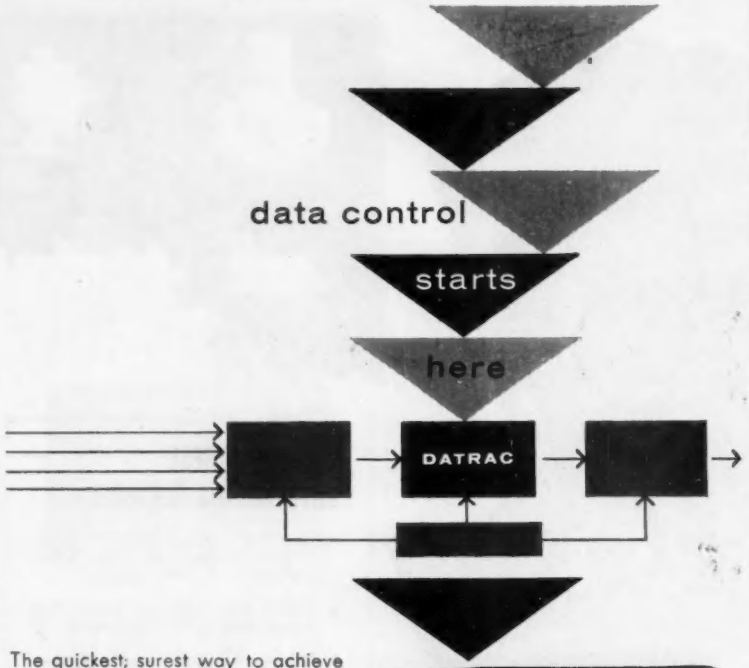

The quickest; surest way to achieve true data control in digital systems is to specify an Epsco Model B DATRAC voltage-digital converter.

RELIABLE — Epsco pioneered the field of high-speed data conversion techniques . . . is today considered its leader. Epsco DATRACS have been field-proven in hundreds of installations, coast-to-coast.

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a certain extent, to lower sales (and thus less need for capacity), but the result could be quite healthy indeed.

FIER Clinic to Examine Metal-Quality Measurement

In the midst of rising costs, the Foundation for Instrumentation Education & Research is holding fast to its policy of education at a bargain for the control engineer and his professional relatives. FIER's latest offering: a conceptual clinic on new instrumentation for metal cutting, a two-day event that will run registrants just $25 for room, board, and tuition. It's hard to go wrong at a price like this.

Actually, FIER is only one of the sponsors. The others are American Society of Tool Engineers and the University of Michigan, Ann Arbor, where the clinic will take place June 26 and 27. Each sponsor is responsible for bringing in a different type of registrant. FIER's assignment: instrument men. ASTE's and the university's: industry representatives and researchers.

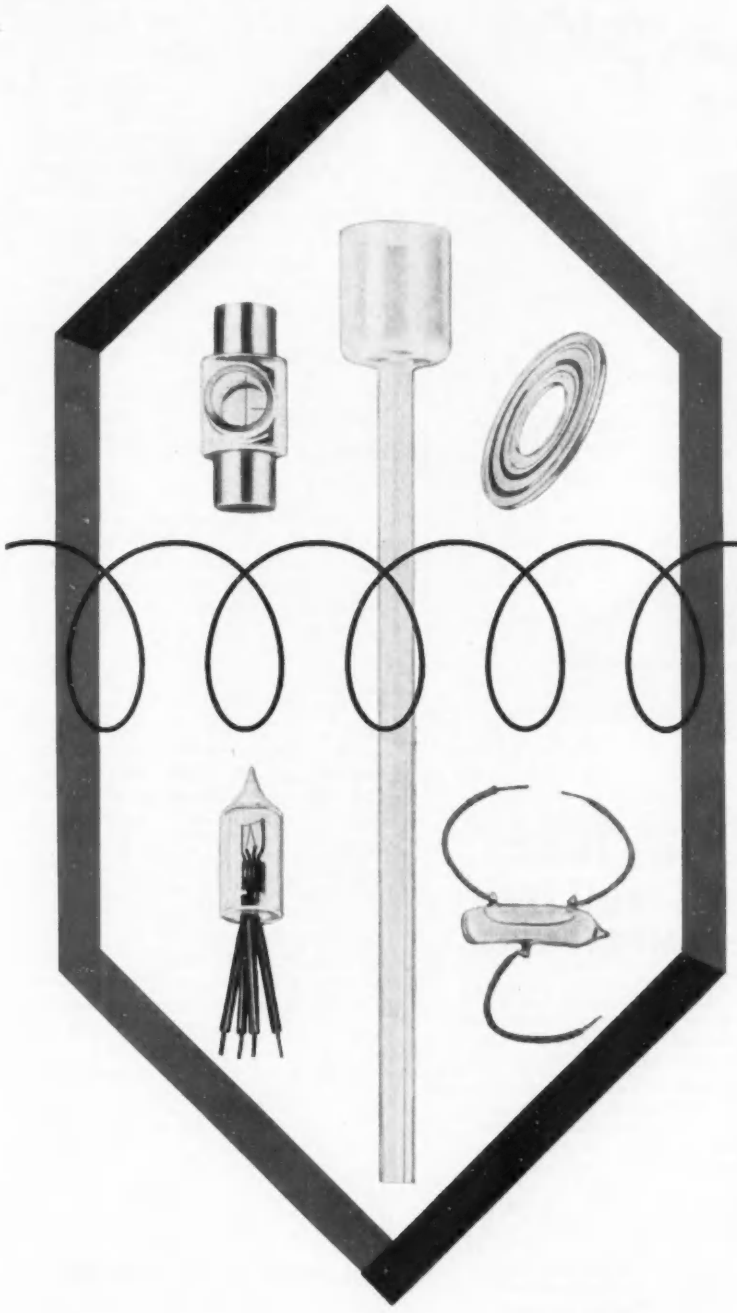
Specific aim of the clinic is to explore what FIER calls "one of the most promising and least understood areas for applied instrumentation: the area of continuous or dynamic metal quality measurement during cutting or allied processing". Send the registration money and any questions to Lloyd Slater, executive director of the Foundation for Instrumentation Education & Research, 527 Lexington Ave., New York 17, New York.

IBM-Germany Is Thriving: Sales Up 25 Percent in '57

IBM Deutschland Internationale Buero-Maschinen Mbh., founded in 1910, today is the biggest IBM company outside the U.S. Last year the Germany-based firm (it has factories in three cities) increased sales 25 percent to $50 million. This year it expects the figure to go over $60 million. Output consists of electronic computers and punched-card machines, electric typewriters, and chronometers.

Monroe Is Flourishing As a Litton Division

It seems Monroe Calculating Machine Co. is doing quite well under the wing of Litton Industries, Inc.



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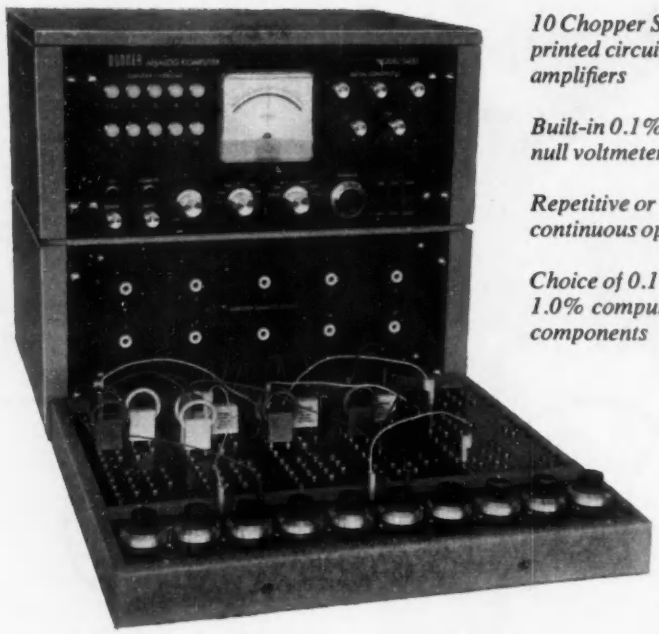


10 Chopper Stabilized printed circuit amplifiers

Built-in 0.1% null voltmeter

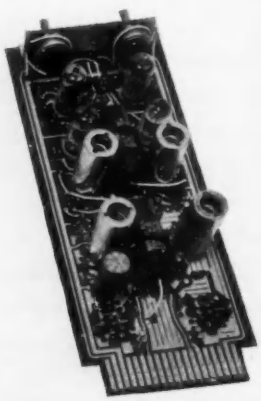
Repetitive or continuous operation

Choice of 0.1% or 1.0% computing components

A NEW Desktop Computer WITH CHOPPER STABILIZED AMPLIFIERS

Donner's new 3400 analog computer combines high accuracy, flexibility, and economy. From its inception, design philosophy dictated the creation of a computer whose performance compared favorably with larger and more expensive equipment.

A complete Model 3400 consists of 10 chopper stabilized amplifiers, built-in null voltmeter and cyclic reset generator, 5 initial condition power supplies and supporting control and metering circuitry. Price of the basic Model 3400 is $2,190. The Model 3430 Removable Problem Board sells for $95. The purchaser can buy either 0.1% or 1.0% passive plug-in computing components according to the requirements of his problems. Two or more 3400's can be slaved together and operated from any one computer. Standard companion non-linear equipment such as function generators, and multipliers is available for operation with the 3400.



Donner engineering representatives are located in principal areas throughout the western world. Your nearest representative will be happy to arrange a demonstration. For the name of your nearest representative and complete technical information on the new Donner 3400, please address Dept. 086.

Model 3101 plug-in amplifier: *dc gain in excess of 50 million; maximum offset of a unity inverter, less than 200 μv/day; drift of unity integrator, less than 100 μv/sec; phase shift of unity inverter, less than 0.5 degrees at 1 kc. These amplifiers are also available for separate sale.*

DONNER SCIENTIFIC COMPANY

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8

WHAT'S NEW

(CtE, Dec. '57, p. 50). Its sales for the first three months since its purchase by Litton are up 5 percent over what they were for the same period of 1957, and its profits are up by even a larger margin. What's more, production quotas for Monroe's new Monrobot IX accounting machine have been expanded to accommodate an unscheduled increase in sales.

Helipot Rubs Out Transit Damage with Polyurethane

"Until four months ago," says Beckman/Helipot Corp., "80 cents of every dollar charged by Helipot accountants to costs of packaging its line of Beckman precision panel meters wound up in the column headed 'repair and handling of units damaged in shipment'." That's not so any more, for Helipot has discovered polyurethane foam, a plastic that can cushion the most delicate instruments against heavy shock. Furthermore, polyurethane has no adverse effect on metal, keeps out moisture, is self-extinguishing in case of fire, and can be die-cut.

Now Helipot simply hollows out two complementary section of polyurethane and places them around its outgoing panel meters. It reports that not a single meter has been damaged in the four months since polyurethane has been in use, and actual packaging expenses have been slashed from $1.17 per unit to 64 cents. That's quite a contrast to the 233 out of every 10,000 meters lost to damage before.

Polyurethane, made by American Latex Products Corp., has other interesting uses, too, Helipot reports. Among them: lining tote trays, sponges, and refrigeration.

Beckman Rebeads Corporate String, Makes It Stronger

When a group of management consultants got through with Beckman Instruments, Inc. recently, the big, diversified West Coast control maker had some new parts in its hair. These included: an increase in the number of directors; a corresponding increase in front-office administration of research, product development, manufacture, corporate sales, industrial relations, and finance, and several new executive positions.

One of these new positions is director of research, another is director of product development, a third is

NEW OHMITE®

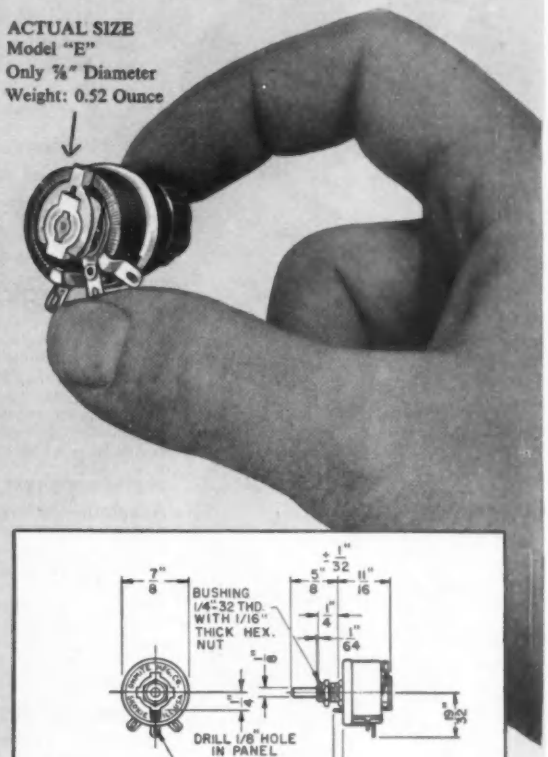
12½ WATT MINIATURE RHEOSTAT

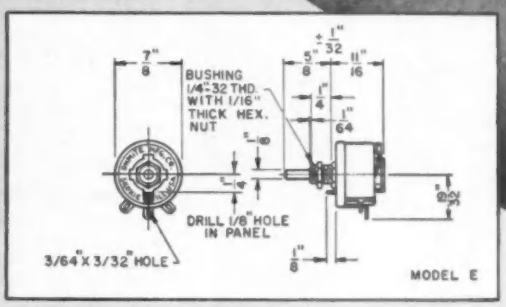
High power handling capability for small size

Newest addition to the Ohmite line of vitreous-enameled rheostats is the new Model "E" miniature 12½-watt rheostat. This new unit is smaller than many one- or two-watt potentiometers. It provides time-tested Ohmite all-ceramic and metal design features for uses where as much as 12½-watt dissipation is required and space is extremely limited. Built to operate at a maximum hot spot temperature rise of 300° C at an ambient of 40° C, Model "E" is also useful for operation at high military ambients, derated linearly to zero at 340° C, attained. Rugged, lasting, power rheostat performance is thus available in such small size that new possibilities in miniaturization and dependability are afforded the apparatus designer.

Like the larger Ohmite rheostats, Model "E" has a ceramic base, and ring-shaped ceramic core. Vitreous enamel holds the turns of wire against shifting, and fastens the base and core together. Also, the Model "E" has a ceramic hub insulating the shaft; a metal-graphite contact; folded spring arm; independent compression spring; slip-ring; a stop directly connected to the shaft. The entire assembly is a miniaturized, dependable version of the time-proven Ohmite power rheostat design. Mounting is by a ¼"—32 threaded bushing. The shaft is ⅛" in diameter. Resistance range: up to 5,000 ohms with 23 stock values; higher values available with OHMICONE inorganic coating. Resistance tolerance: ±10%. Torque: 0.1 to 0.2 pound-inch. A small finger-grip knob, in keeping with the rheostat dimensions, is available.

Special length shafts and bushings, screwdriver shafts, locking type bushing, tandem mountings, enclosures, etc., similar to the variations available on the larger rheostat, can be provided upon specific request.





INDUSTRY'S MOST COMPLETE LINE OF RHEOSTATS

Now 11 Sizes! — 12½ to 1000 Watts

All sizes available from stock in a wide range of resistance values, including the NEW Model "E." Ten sizes are available to meet MIL-R-22A requirements in *each* of the 26 type designations.

RHEOSTATS RESISTORS RELAYS
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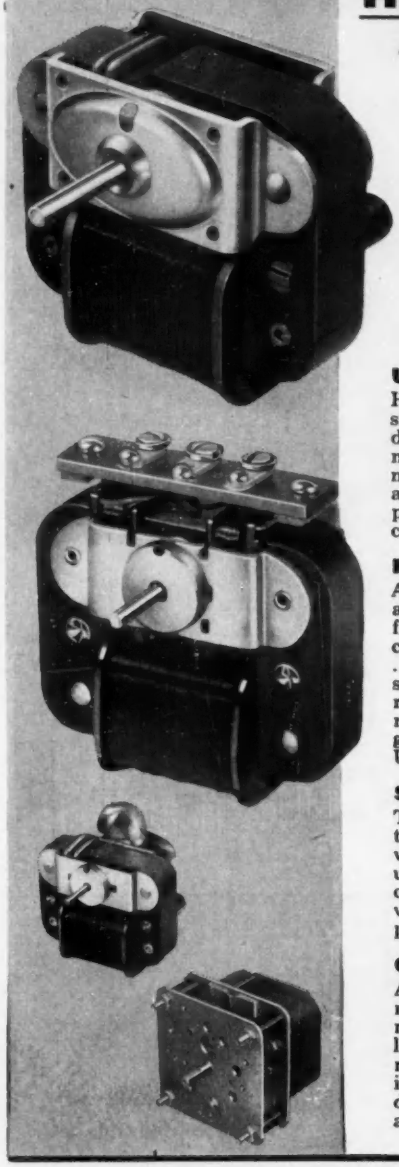
wide variety . . . fast delivery



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Put these high-quality, precision-made motors into your product and be assured of long, trouble-free service — at a reasonable price. Look at these "plus" features:

- High torque — Small size
- Large oil reservoirs
- Porous bronze or ball bearings
- Long life, rugged construction
- Exceptionally quiet-running

UNIDIRECTIONAL

High torque for quick, positive starting. Excellent for driving dictating machines, pumps, vending machines, fans, blowers, office machines, vaporizers, and other applications requiring dependable performance under adverse operating conditions. Up to 1/20 hp.

REVERSIBLE

Adaptable to a variety of control circuits and power requirements. Outstanding for various applications requiring a compact, powerful, fast-reversing motor . . . such as servo-mechanisms, remote switching and positioning devices, recording instruments, voltage regulators. Available with or without gear trains. Open or enclosed types. Up to 1/25 hp.

SYNCHRONOUS

These motors combine accurate timing and high torque with light weight and compactness. Widely used for x-ray timers, microfilm cameras, recorders, timers, and viscometers. Develop 30 times the power of ordinary clock motors.

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Available with enclosed or open gear reductions. Precision-machined gears running on accurate centers assure long life under heavy loads. Wide range of gear ratios. Used extensively in vending machines, electric signs, displays, high-voltage switchgear and remote positioning controls.

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Small Motors • Automatic Controls • Industrial Instruments • Aircraft Controls
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WHAT'S NEW

corporate director of manufacturing and a fourth and fifth are director of corporate sales and director of industrial relations. Each one, to be filled by promotion, will be concerned with coordinating, consolidating, and acting as liaison for, the widespread Beckman activities with which it is connected.

Two others are not "promotion" positions. They are: executive vice-president and corporate controller. The former will undertake many duties associated with daily operations, permitting President Arnold O. Beckman to give more attention to such operations as research and long-range objectives.

As a result of the increased direction from the top, each Beckman division will become primarily a manufacturing, selling, and servicing entity, concentrating on products assigned to it to reach established performance goals based on capital investment and other factors. In addition, division managers will be able to concentrate on "the basic profit-making functions of making and selling."

Dynamic Testing Practice Passes Publication Milestone

With its publication as Tentative Recommended Practice RP-26:1, the new ISA recommended practice for dynamic-response testing (CtE, April '57, p. 37) clears the last hurdle on the way to a permanent place among ISA standards.

Said the association in announcing the new publication, "The need for generally accepted data and industry-wide acceptance of dynamic test procedures has grown immensely in recent years. Such information is now a vital part of 'feedback theory' and 'systems engineering'. Without uniform information, procedures, and values, further progress in instrumentation and modern industrialization would be seriously impeded."

Actually, only the first portions of the practice have been published; these are the general description, and sections dealing with specific types of instrumentation: ISA RP-26:2, dynamic response testing of devices with pneumatic output signals, and ISA RP-26:3, dynamic response testing of devices with electric output signals. Main differences between 26.2 and 26.3 are the word "pneumatic" and "electric" and, of course, the load configurations.

Sections on automatic valves and

other final control elements, and on display and recording equipment, are still to come. In addition, ISA is considering extending this work to include hydraulic and aeronautical instrumentation.

Another ISA practice published recently has to do with selecting materials for use in high-level nuclear radiation fields. No standards are set here, or procedures codified; instead, available and significant data on a critical area is presented.

All of these practices are still in their rough draft form, but as such, they can be obtained by writing to Fred H. Winterkamp, chairman of RP-26 "Dynamic Response Testing", P. O. Box 993, Charleston 24, W. Va.

Patent Button Zeroes In On Control in Electronics

The Patent Button Co., 100-year-old New England garment-button maker, has entered a pushbutton business: electronics.

In the middle 40's, Patent Button traditionally a "slow-growth" company, began examining several "rapid-growth" fields to satisfy a new need to diversify. First it settled on the manufacture of instruments for medical and industrial research, and organized its Patwin Instrument Div. Then, just a few years ago, it turned to the manufacture of components for computers, and for electronics in general.

Now the Waterbury, Conn. firm has appointed Frazier O. Stratton sales manager for electronic components and completed the sale of its research instruments to American Optical Co. Stratton, an old hand at engineering and selling electronic components, most recently was vice-president of Kinsman Electronic Organ Co. Before that he was chief engineer for Sterling Engineering Co., a subsidiary of AMF. At Patent Button he will concentrate on the new Magneline digital indicator, an Epsco-designed magnetically positioned device on which PB now owns the patent rights.

American Optical has added the recording and manual electro-polarizers of PB's Patwin Div. to its line of scientific instruments produced in Buffalo, N. Y. Also added at Buffalo: Patent Button's former sales manager for Patwin instruments, G. Tatoian.

Hughes Aircraft Inaugurates Share-the-Knowhow Plan

An agreement with Monogram Precision Industries, Inc., licensing Monogram to manufacture a new line of very wide band ferrite isolators, marks the start of a new program at Hughes Aircraft, to share its technical knowl-

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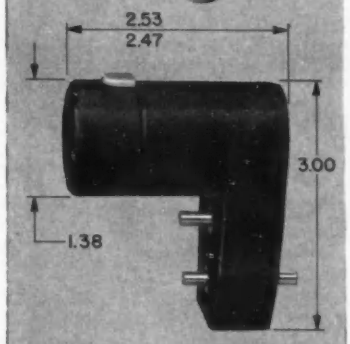
d-c gearhead motors

NEW

multiple output motor requires little space

Equipped with three output shafts, this compact, powerful gearhead motor handles multiple-use applications in limited space. Permanent magnet motor has patented symmetrical, progressive lap-type armature winding, which provides true electrical balance . . . superior commutation . . . low radio noise output. Elementary control circuits provide dynamic braking. Explosion-proof enclosure. Temperature range: −65°F to +200°F.

- **Gear ratios available up to 41,176 to 1**
- **Withstands sudden reversals**
- **12 oz. (approx) weight**



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For driving AC servo motors in industrial and military servo systems which require hi-power, fast response and (static) high reliability.

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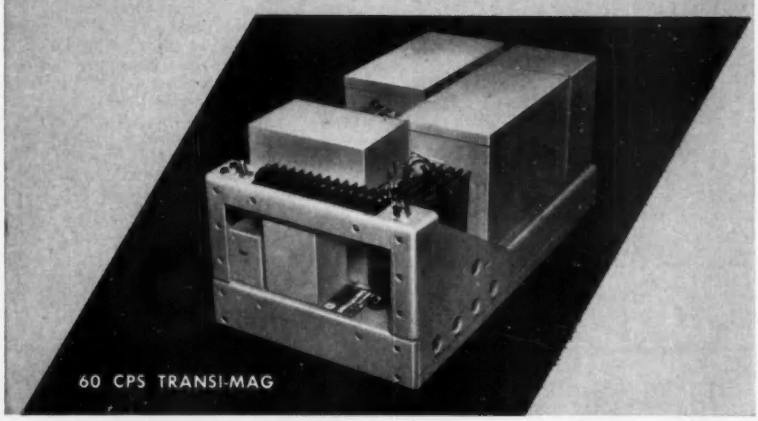

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MODEL A.C. INPUT / D.C. INPUT	MA-1502 / MA-1511	MA-1559 / MA-1561	MA-1572 / MA-1581	MA-1602 / MA-1611	MA-1702 / MA-1711	MA-1802 / MA-1811	MA-1902 / MA-1911
MAX. POWER OUTPUT WATTS	50	100	120	175	650	1900	2800
TYPICAL SERVO MOTOR LOAD	DIEHL FPF 49-9	DIEHL FPF 49-12-1	DIEHL FPF 66-11-1	DIEHL FPF 85-18-1	DIEHL ZP 105-2212-1	DIEHL ZP 143-2247-1	DIEHL ZP 162-2207-1
SENSITIVITY	A.C. INPUT – 0.5V A.C. FOR FULL POWER OUTPUT D.C. INPUT – 2.5 MA D.C. FOR FULL POWER OUTPUT						
RESPONSE	0.1 seconds						
AMBIENT TEMPERATURE	– 55°C. to + 71°C.						

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West Coast Division

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WHAT'S NEW

edge with other companies. A broad variety of electronic devices is involved. The ferrite isolators in the agreement with Monogram's Cascade Research Div. (Los Gatos, Calif.) transfer energy efficiently in one direction, and prevent its reflection back to microwave generators under variable load conditions. A major use is in improving the operation and extending the life of microwave tubes.

Still More Control Firms File Their Annual Reports

Annual reports by some companies in the control field did not appear in the CtE survey in May (page 52) nor in earlier stories. Among these:

General Electric Co.–Sales up 6 percent, from $4,090,015,685 to $4,335,664,061; net profit up from $213,756,849 to $247,851,871.

El-Tronics, Inc.–Sales up from $1,008,718 to $2.8 million; net loss of $100,000, compared to a net loss in 1956 of $906,942.

International Telephone & Telegraph Corp.–Sales up from $559,625,294 to $653,469,480; net income down from $28,109,946 to $22,412,814.

Marchant Calculators, Inc. (see Note 1 below)–Sales down from $27,800,653, to $25,561,027; profits down from $1,951,559 to $562,419.

Milton Roy Co.–Sales up from $3,635,346 to $4,338,499; net profit up from $172,113 to $179,394.

Parker-Hannifin Corp.–Sales up from $20,586,671 to $25,495,628; earnings up from $1,255,103 to $1,301,939.

Servomechanisms, Inc.–Sales up from $18,138,280 to $23,591,781; net profits down from $615,606 to $308,776 (due to a higher percentage of sales ploughed back into R&D).

Sylvania Electric Products, Inc.–Sales up from $332,344,159 to $342,957,061; net profit down from $14,835,389 to $12,655,839.

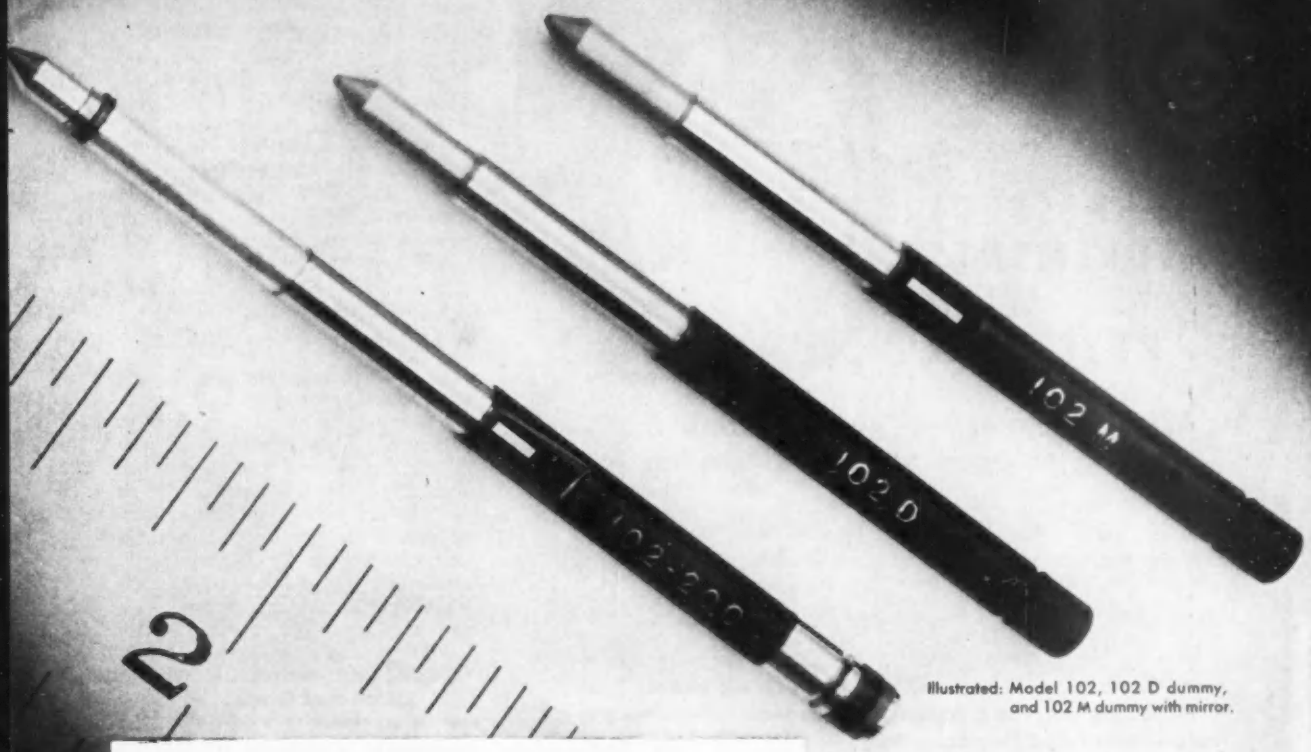
Technitrol Engineering Co. (see Note 2 below)–Sales up from $1,568,392 to $1,718,952; net profit up from $62,371 to $154,586.

Western Electric Co.–Sales up 4½ percent, from $2,372,725,739 to $2,480,613,068; net profit up from $75,054,119 to $84,608,346.

Note 1: Possibly a direct result of the decline in both sales and profits is the contemplated merger of Marchant with Smith-Corona, Inc. The details are still to be worked out, but it is reported that Marchant share-

MI

Galvanometers



Illustrated: Model 102, 102 D dummy, and 102 M dummy with mirror.

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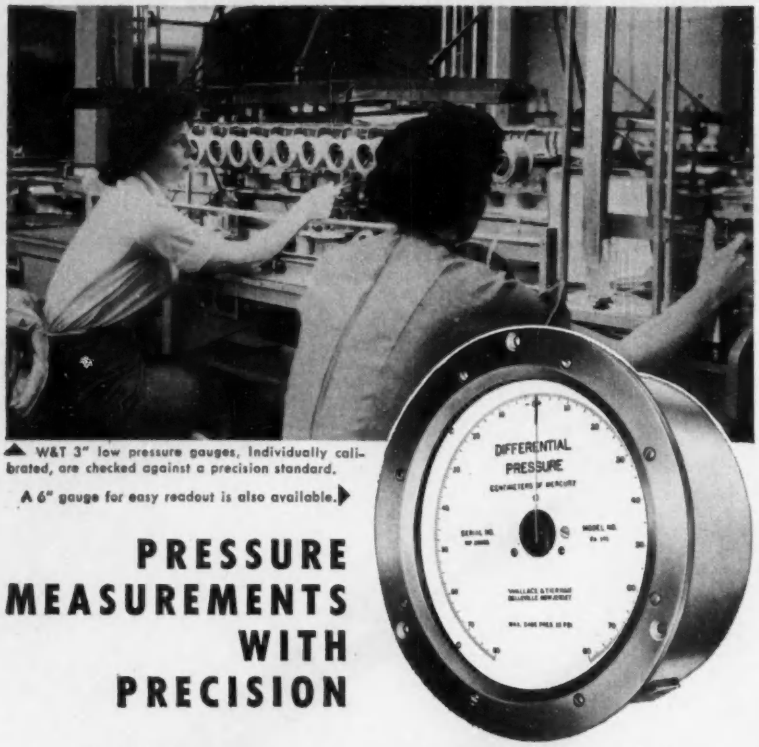

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A 6" gauge for easy readout is also available. ▶

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service: gauge pressure; differential pressure; vacuum determinations; or as compound pressure-vacuum gauges with zero center; **accuracy:** 1 part in 300; **sensitivity:** 1 part in 500; **minimum range:** 0 to 10 inches H_2O; **maximum range:** 0 to 400 inches H_2O; intermediate ranges of pressure or vacuum in any pressure equivalent are also available.

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M-31

holders would receive one and a quarter Smith-Corona shares for each of their own. The merger would also enable both companies to make a stronger bid in the electronic data processing field. Marchant has done considerable development work in EDP, but decided last year to get out. Now it may be back in again, its calculators backed by S-C's typewriters and teleprinters.

Note 2: Technitrol has announced a coming merger with L & O Research & Development Corp. of Wayne, Pa. Though it won't be completed until later this year, L & O's President A. F. Cary has already moved to Technitrol as vice-president of product development, and both companies have started work on an economically sound facsimile system.

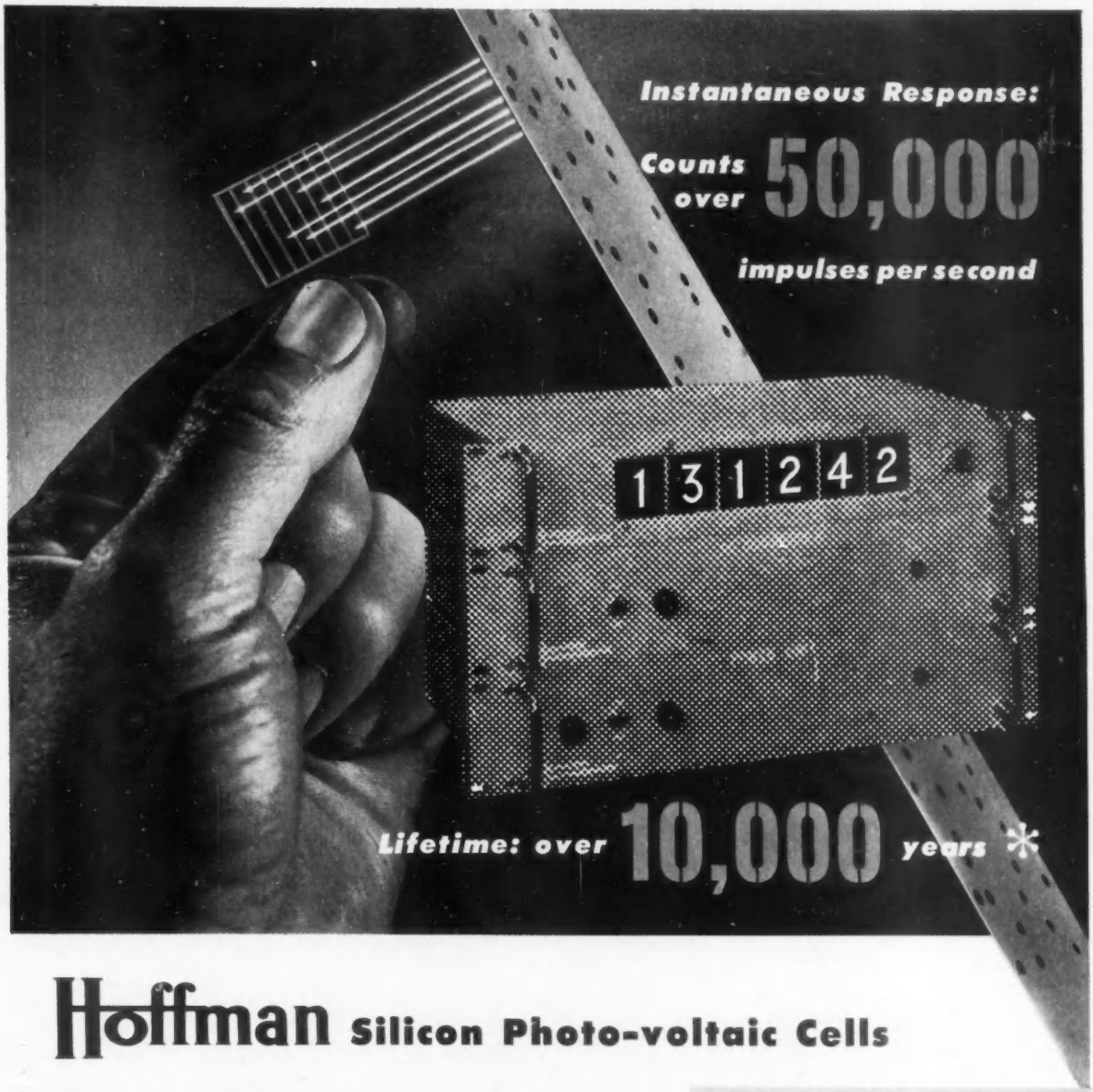
7 Consulting Firms Rent A Computer, Open Business

Small companies may not need a computer as often as large companies, but when the need is there, it is no less acute. That is why seven consulting engineering firms, each one unable to support a computer on its own, have formed a computing center on a cooperative basis. The name: Midwest Service, Inc., Decatur, Ill. The angle: each company will purchase a certain amount of time on a mutually-leased computer (a Bendix G-15D) to make the annual budget.

Said Midwest Computer's President E. M. Chastain of Decatur: "For the smaller engineer, the situation has reached the point where it's a matter of get a computer or get out of the race. We saw we needed a computer but we didn't have enough work to justify full-time use of one. We then got the idea of forming a corporation with other nearby firms as participating members.

"The small engineer wants his shop to be as good as the larger ones, and he wants his share of a project to be of the same quality. He can concentrate as much knowledge and know-how into a section as the larger one can in five or more. With a computer available, the small engineer can maintain his competitive position."

But Midwest Computer is only one of several computing and/or consulting centers that have been opened recently. Others: IBM Italia, the first for Italy, opened in May by IBM, with a 650 built at Sindelfingen, Germany; and Ducker-Singer Co. of Birmingham, Mich., formed with the idea of developing a product or line



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Response time is less than 20 microseconds allowing for instantaneous control. Replacement problem virtually eliminated due to permanent life-time diffused p-n junction.*

Compact size results in a greater number of control circuits for a given area, at less cost. These self-generating (Photo-Voltaic) "cells" eliminate the need for external power supplies and provide maximum reliability and efficiency under severe temperature variations (from −65°C to +175°C and higher).

Our extensive laboratories and design facilities are available to aid you in the solution of your control problems. Write us for further information.

*(Per R.C.A. Laboratories, Princeton, New Jersey Report No. 212-PH-55-91 (1114), April 15, 1957).

Applications

- Punched Tape and Card Readouts
- Infrared Sensor Devices
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- Automatic Counting Devices
- "Pinhole" Detectors
- Remote Switching Controls
- Conveyor Line Control
- "Hot-metal" Detector
- "Loop" Control
- Smoke and Flame Detector Devices
- Photo-electric Control Applications

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WHAT'S THE CATCH?

The catch or latching arrangement on all these Sigma relays is a permanent magnet. While this fact is not fraught with serious or far-reaching consequences, magnetic latching does have advantages worth considering. Since there are no triggers, catches or springs to wear out, magnetic latching relays do not fear early commitment to an eleemosynary institution. They do not continuously nibble a little stand-by power, adding their own little body warmth to the already stuffy environment; nor do power interruptions make them change position. What the armatures of these Sigma relays *do* do is stay where the last coil signal sent them, moving to the other fixed position only when a resetting signal comes along.

An up-to-date inventory shows that there are now five Sigma magnetic latching relays available, with the following distinguishing traits. **SERIES 6** will switch 2 or 5 ampere loads on inputs from 22 to 450 mw., with contacts up to 4PDT; useful in memory circuits, fast enough for follow-up systems, reliable latching contactor. **SERIES 61** is a modification of the "6", with DPDT contacts capable of switching 20 ampere loads on 225 or 450 mw. signals; small, considering its ratings. **SERIES 32** is the newest and smallest of the group; DPDT, measures 0.800" x 0.400" x 0.900" high, max., has pins spaced equally on 0.200" centers; price is low. **SERIES 72** is the most sensitive (0.3 — 2.0 mw.), and is designed for bounce-free, high speed switching. Sensitivity is adjustable, contacts replaceable. **SERIES 73** is a small hermetically sealed SPDT type for use in miniature devices and guided missiles. Dimensions ¾" dia. x 1 11/16" high. Contacts rated 1.5 ampere, sensitivity 6 mw. and 12 mw.

If any of these magnetic latching relays (Sigma Form "Z") offer the characteristics you're looking for, write for more data. If they don't, write anyway and tell us what you expect. Maybe one of us could be talked into making a small modification, so that a Sigma relay *will* work.

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of products to meet the needs of the market within the limits of the client's facilities. President is William H. Ducker, engineer and inventor.

Other New Companies

John-Lawrence Associates, organized by Lawrence Lowy, formerly eastern regional manager of petroleum sales for the Proportioneers Div. of B-I-F Industries, Inc., to apply quality control techniques to blending, metering, and packaging—in New York City. Activities will be directed primarily toward the petroleum and petrochemical industries, with which Lowy is well acquainted.

The Hydrodyne Corp., formed by two ex-Bendix Aviation men to manufacture various fluid control products for the aircraft and missile industries—in North Hollywood, Calif. President is J. H. Overholser, formerly assistant general manager of Bendix-Pacific, and before that executive vice-president of Hydro-Aire, Inc., which he helped found in 1943; and executive vice-president is Robert T. Skinner, owner of the Skinner Seal Co. and formerly vice-president of Skinner Purifiers, Inc., which is now a Bendix division. "We are particularly interested," said Overholser, "in high and low temperature, and also high pressure problems and products involving exotic fuels, including cryogenics, atomic energy, and other difficult to control fluids and gases."

Hobado Engineering Co., to specialize in project analysis and mechanical and electrical design—in Beverly Hills, Calif.

New Divisions and Groups

A Military Products Div. for **Singer Mfg. Co.,** whose new Haller, Raymond & Brown Div. (CtE, April, p. 40) is the feature building block. Also in the structure: Singer's Diehl Mfg. Co. and its Bridgeport Works. Special areas of the new unit are electronic computers, electromechanical timers, hermetically sealed high-voltage switches, and radar and infrared reconnaissance equipment. Frederick W. Howells, formerly manager of military sales for the Columbus Div. of North American Aviation, is in charge. Branch offices will open soon in Washington, D. C., and Dayton, Ohio.

An Astronics Div., formed by **Lear, Inc.** "to cope more efficiently with the new requirements for accessory

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PREMISE | Tomorrow's *industrial* Control Systems will utilize the most advanced technologies of the Control Sciences.

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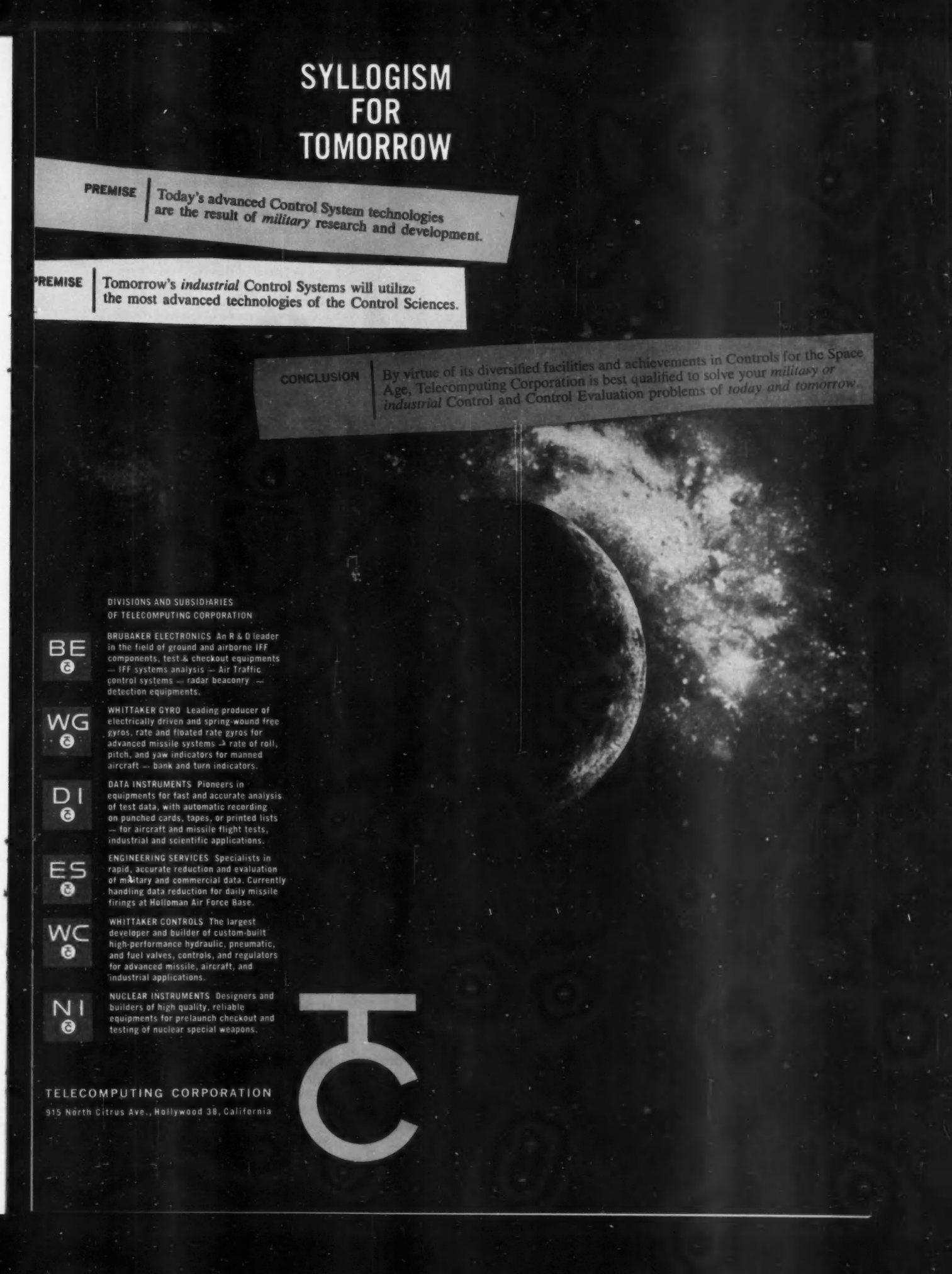

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BE — BRUBAKER ELECTRONICS An R & D leader in the field of ground and airborne IFF components, test & checkout equipments — IFF systems analysis — Air Traffic control systems — radar beaconry — detection equipments.

WG — WHITTAKER GYRO Leading producer of electrically driven and spring-wound free gyros, rate and floated rate gyros for advanced missile systems — rate of roll, pitch, and yaw indicators for manned aircraft — bank and turn indicators.

DI — DATA INSTRUMENTS Pioneers in equipments for fast and accurate analysis of test data, with automatic recording on punched cards, tapes, or printed lists — for aircraft and missile flight tests, industrial and scientific applications.

ES — ENGINEERING SERVICES Specialists in rapid, accurate reduction and evaluation of military and commercial data. Currently handling data reduction for daily missile firings at Holloman Air Force Base.

WC — WHITTAKER CONTROLS The largest developer and builder of custom-built high-performance hydraulic, pneumatic, and fuel valves, controls, and regulators for advanced missile, aircraft, and industrial applications.

NI — NUCLEAR INSTRUMENTS Designers and builders of high quality, reliable equipments for prelaunch checkout and testing of nuclear special weapons.

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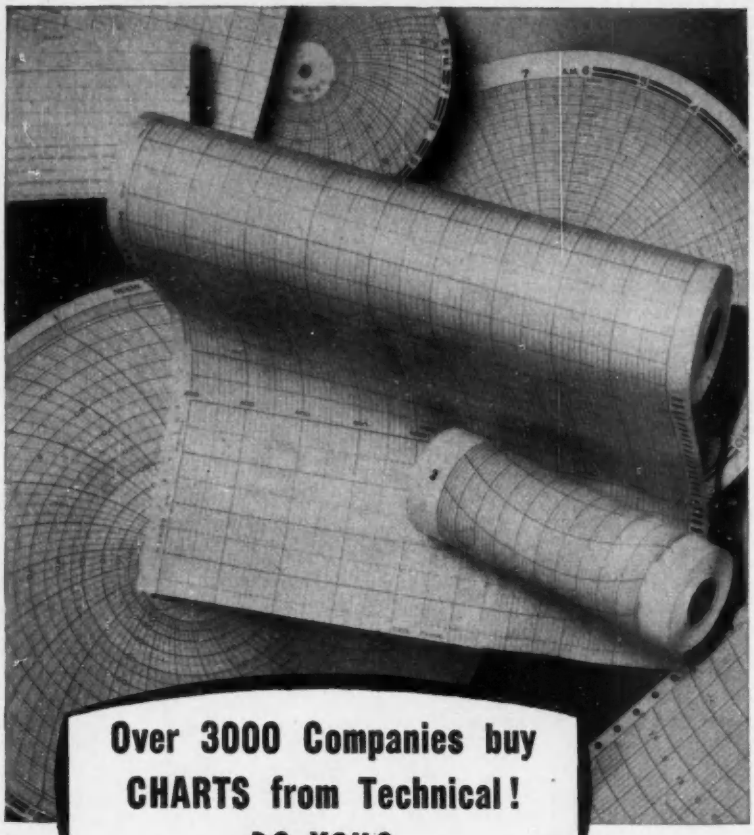

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WHAT'S NEW

equipment under the weapons system concept of military operations, and to integrate more fully Lear products into the modern military weapons." Specifically, the division will concentrate on flight control and guidance systems and related subsystems. Manager is James P. Brown, formerly head of West Coast operations for the Grand Rapids Div.

Control Systems Co., a new division of **Hancock Industries** of Jackson, Mich., formed to manufacture and market the Hancock Telecontrol production control and monitoring system. Manager is Carl S. Saltzman, formerly with Underwood Corp. The Hancock subsidiary on the West Coast, Computer Measurement Corp., is active in the design phase of the new system.

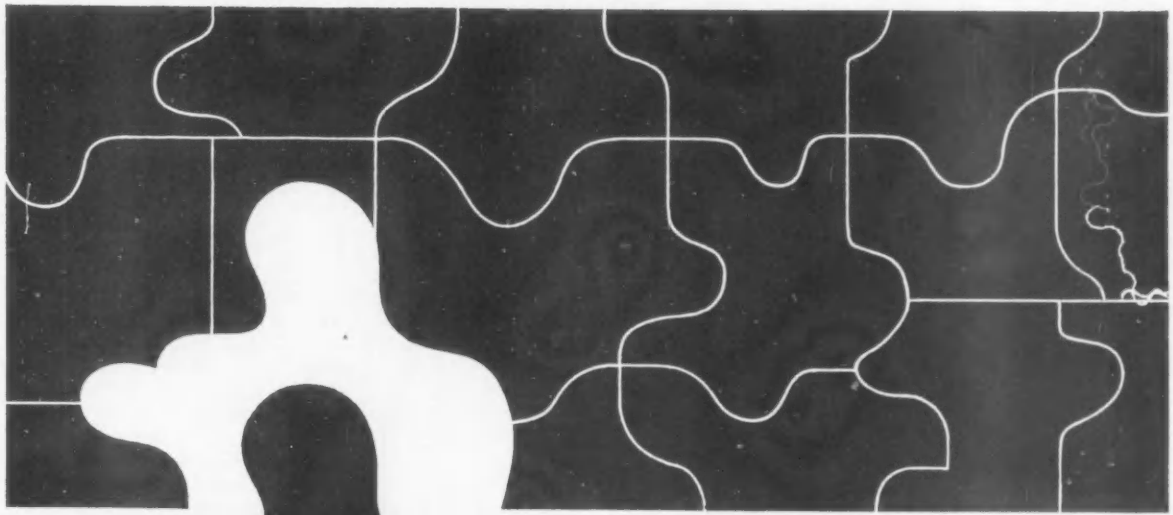
A Glennite Instrumentation Div., to develop and manufacture high-accuracy sensing devices, data-handling systems, and automatic digital computers for **Gulton Industries, Inc.** Gulton has formed the division out of four existing departments in a move to exploit the systems concept. The departments: shock and vibration equipment, pressure sensing transducers, instrumentation recorders, and instrumentation systems. General manager is Abraham I. Dranetz, director of engineering. Under his direction, Glennite will train its sights principally on the process industries.

A new flowmeter calibrating laboratory for Cox Instruments Div. of **George L. Nankervis Co.** Certification and recalibration, a special service of the laboratory, is expected to provide transfer standards for correlation programs. Ten calibrations can be conducted simultaneously, using any of 26 different calibrating fluids.

An "Astrionics" Div. in **Radiation, Inc.,** to specialize in flight and data-recording instrumentation for space vehicles. Director is Lawrence Gardenhire, formerly with White Sands Proving Grounds and chairman of the ISA's Telemetering Committee. He headed the National Telemetering Conference last year.

An Engineering Dept. for the British Div. of **Benson-Lehner Corp.** at Southampton, England. Division director is E. J. Petherick.

A Missile Components Group (MCG) for **Electro-Snap Switch & Mfg. Co.,** to concentrate on the reliability phase of electromechanical components and systems for missiles. The group will work on improvements in design, testing, and production.



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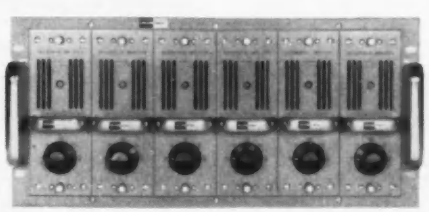
These are just a few of the many outstanding features of the Model 114A differential DC amplifier . . . features that make this amplifier *really work* in instrumentation systems...features that will help solve *your* instrumentation problems today.

Ideal for thermocouple amplification, the 114A eliminates ground loop problems; allows the use of a common transducer power supply; permits longer cable runs; drives grounded, ungrounded or balanced loads, and can be used inverting or non-inverting.

For additional information and technical literature on this exceptional instrument, write or call KIN TEL – the world's largest manufacturer of precision, chopper-stabilized DC instruments.



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Beckman Servomotor-Rate Generators whirl away on a common shaft, run far ahead of the field. Horse and jockey share a stainless-steel, unitized housing. Linear output from the generator can be applied as tachometric feedback to keep a tight rein on motor response, or as computing element in coarse calculators. Here's another champion from Helipot.
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IMPORTANT MOVES BY KEY PEOPLE

Ragazzini Going to NYU As Dean of Engineering

John R. Ragazzini (CtE, Jan. '56, p. 15), chairman of Columbia University's School of Engineering since 1954, has been named dean of the College of Engineering of New York University. He will assume his new duties July 1, or at the end of the present semester, taking over from Norman N. Barish, who has been acting dean during the current academic year. Thorndike Saville, who held the dean's post from 1935 to 1957, is now dean emeritus.

The administrative portion of Ragazzini's duties at Columbia will be assumed by EE Prof. Ralph J. Schwarz, who consequently becomes a member of the university's executive staff. No one has been named as yet to fill Ragazzini's teaching shoes.

Ragazzini, a product of New York City engineering schools (City College, Columbia) joined the City College EE faculty in 1935, the Columbia faculty in 1941. From 1951 to 1953 he directed Columbia's Electronic Research Laboratories, and a year later became chairman of the engineering school. He is an authority on electronic computers and control systems, and is creator of the "Ragazzini Computer" or "Ragatrack", an Air Force device that automatically guides interceptor planes toward approaching enemy aircraft. He is also one of the two consulting editors for the McGraw-Hill Book Co.'s new series in control systems engineering. The other is CtE's William E. Vannah.

Professor of EE Takes Dean's Post at Stanford

Another school of engineering, Stanford's, also has a new dean, Joseph M. Pettit, professor of electrical engineering and winner of the IRE's achievement award in 1952. He replaces University Provost Frederick E. Terman, who has held both positions, Pettit's and his own, since 1955.

Pettit holds a Presidential Certificate of Merit for his war work in electronic circuitry at Harvard's Radio Research Laboratory and in the China-Burma-India theater. Shortly after the

A Measurement Once Every Second with the IMPEDANCE COMPARATOR

The G-R Type 1605-A Impedance Comparator serves as the "brain" in a Semi-Automatic Tester designed for checking components on printed-circuit subassemblies.

PHOTO COURTESY BENDIX RADIO DIVISION OF BENDIX AVIATION CORPORATION

The Comparator indicates directly on two panel meters the differences in magnitude and phase angle between unknown and standard impedances. No manual balancing is required.

As used with the Semi-Automatic Tester, the Comparator's panel meters are disconnected. Comparator metering voltages, proportional to impedance-magnitude difference (in per cent) and phase-angle difference (in radians), are amplified by the Tester and compared against d-c reference voltages which correspond to allowable tolerances. Printed-circuit components which produce voltages in excess of pre-set tolerances are automatically rejected.

Relays have been added in the Tester so that Comparator impedance ranges can be switched automatically by a remote punched-card programmer. Since programs are switched every second, three continuously running oscillators are used as fixed-frequency sources for the Comparator.

The Unit was constructed by Bendix Radio Division under sub-contract for IBM and the United States Air Force.

Why The GR Impedance Comparator Was Selected For Automatic Sorting:

- ★ Indicates *both* impedance magnitude and phase angle without knob manipulation.
- ★ D-C voltages proportional to percentage deviation from standard are provided.
- ★ No excess switches or complex controls.
- ★ Excellent guard circuitry permits long cable runs, which are usually necessary in automatic equipment.
- ★ Wide impedance range, high measurement accuracy.
- ★ Constructed for long, reliable service.
- ★ Practical size and weight.

COMPARATOR SPECIFICATIONS

Wide Range of Internal-Test Frequencies
100, 1000, 10,000, and 100,000 cps.

Impedance Ranges
Resistance: 2 ohms to 20 megohms
Capacitance: 40 $\mu\mu$f to 500 μf
Inductance: 20 μh to 10,000 μh

Direct-Reading Meter Ranges
Impedance-Magnitude Differences:
0.3%, 1%, 3%, and 10% of full scale.
Phase-Angle Differences:
0.003, 0.01, 0.03, 0.1 radians full scale.

Over-All Accuracy
3% of full scale (0.01% over-all accuracy on 0.3% impedance magnitude range).

Price: $790

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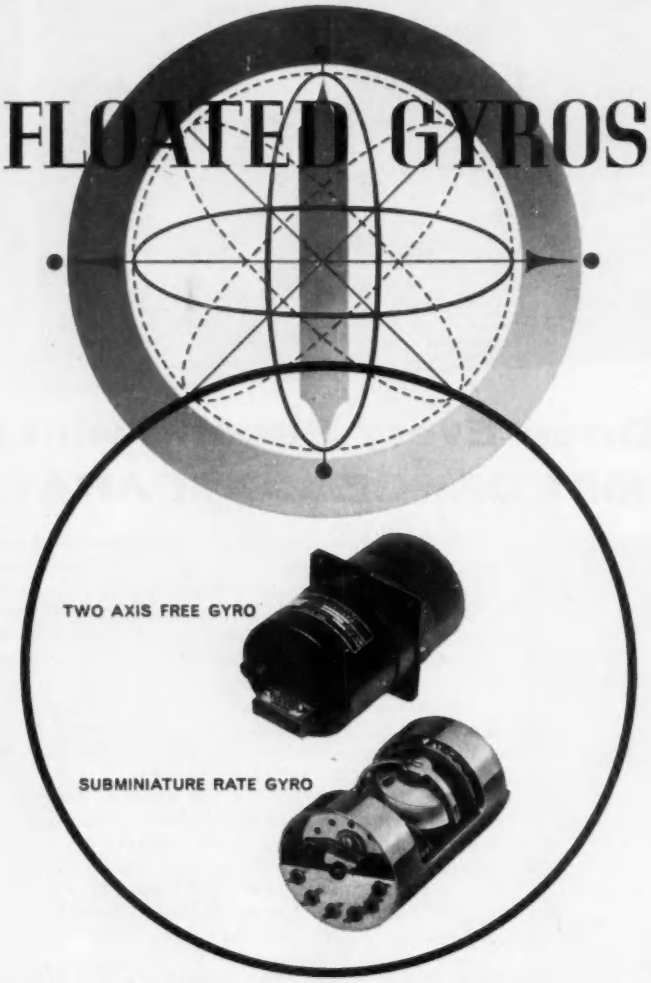
FLOATED GYROS



Daystrom Pacific designs, develops and manufactures a complete line of floated 2 axis free gyros and floated rate gyros in a variety of standard sizes and configurations for auto-pilot and stabilizing applications in the aircraft and missile industry.

Daystrom Pacific, to better serve the customer, has standardized all basic components to reduce cost and excessive lead time.

Other standard instrument products include:

- angle of attack vanes
- sequence timers

Development programs are underway in numerous system projects:

- Inertial guidance systems
- Ground alignment equipment
- Flight data computers
- Floated stable platforms

For further information about Daystrom Pacific—their products and services—please contact the factory direct.

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war (1947) he left Airborne Instruments Laboratory, Inc., where he was in charge of receiver development, to join the Stanford faculty. He was named associate dean of engineering in 1955. He is a fellow of the IRE and a member of the Army Scientific Advisory Panel.

Tennessee's Dean Emeritus to Receive NSPE Award

Still another top-level engineering educator, Nathan W. Dougherty, dean emeritus of engineering at the University of Tennessee, is in the spotlight: he has been chosen to receive the 1958 NSPE Award. NSPE cites his "outstanding leadership in his profession as evidenced by his devotion to the advancement of engineering education, his sympathetic encouragement of students of engineering, his zealous promotion of the ideals and principles of his profession, and his humanitarian interest in his fellow men."

Dougherty was on the Tennessee faculty for 40 years before his retirement in 1956. He had been dean of engineering since 1940. Today he is a consultant for the Arnold Engineering Development Center, Tullahoma, Tenn. He will receive a plaque at the NSPE's annual meeting in St. Louis later this month.

Big Brass Brightens Up R-W's Space Laboratories

Three new engineering vice-presidents are helping to fill out Ramo-Wooldridge's new Space Technology Laboratories. They are: Milton U. Clauser, V-P and director of the Physical Research Laboratory; Allen F. Donovan, V-P and director of the Aeronautics Laboratory; and William F. Duke, V-P and associate director of the Systems Engineering Div.

Just prior to joining R-W in 1954, Clauser was head of the School of Aeronautics at Purdue University and a consultant to GE on aircraft nuclear propulsion. He is a fellow of the Institute of the Aeronautical Sciences. Donovan, who came to R-W in 1955, and Duke, who came in 1956, are associate fellows of the IAS.

Burroughs, Rem-Rand Others Name Presidents

The following companies have named new presidents: Burroughs Corp. (Ray R. Eppert), Texas Instruments, Inc. (Patrick E. Haggerty),

advertisement

air circuitry:

a sales tool for you—Air is booming as an industrial control medium. Air Circuitry* has recently been applied to jobs where it never would have been considered a few years ago! Westinghouse pneumatic engineers have designed and installed Air Circuitry systems for original equipment which have boosted production and cut time and labor expenses for a wide variety of industries including electronics, textiles, automobiles, chemicals, and aircraft.

The benefits of advanced air control are well known among plant engineers. But you can apply these advantages with the same happy results in *your design* of machinery used in manufacturing operations.

SELLING ADVANTAGES—No other medium offers such safety . . . such dependability. Above all, only air can offer such economy: the medium is free and available in limitless supply; the devices are not expensive; and repairs can be made easily by unskilled personnel. These are all-important factors—factors which *sell* factory and machine shop supervisors!

SEE FOR YOURSELF. We'll send a qualified control engineer to your plant. He will show you if and how pneumatic control can improve your present design, and he'll estimate the cost of conversion. If we can't give you simpler, more reliable controls, you don't owe us a cent; our service is free.

Let us study your control systems. Let us improve them, with air. Just write to Westinghouse Air Brake Company. Industrial Products Division, Dept. RS-6, Wilmerding, Pennsylvania. Give us a description of your line of machinery, and the type of control it is now using. We'll do the rest.

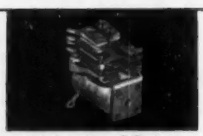
Remember, Westinghouse has led the world in the design and manufacture of pneumatic devices for more than 90 years. We bring world-wide experience to the solution of your control problems. We bring world-wide service to those who use machines equipped with Westinghouse Air Circuitry.

*AIR CIRCUITRY is the Westinghouse term for application of pneumatic control systems to industrial production operations.

LOOKING FOR THE TELEPHONE TYPE?

TRY THIS NUMBER TQ-2C/24VD

(At right) Advance TQ type is our smallest telephone relay: Length, 1 11/32"; Width, 21/32"; Height, from 1 1/32" to 1 13/32".



SPECIFICATIONS

Coil resistance, 2C: From 40 Ohms at 6 volts, DC, to 12,000 Ohms at 110 volts, DC.

Coil resistance, 6C: From 10 Ohms at 6 volts, DC, to 5,000 Ohms at 110 volts, DC.

Nominal power required: 2C, 1.0 watts nominal (appr.); 6C, 3.0 watts nominal, (appr.).

Contact rating: 3 amps resistive, 1 amp inductive at 115 volts AC or 26.5 DC.

Contact arrangement: Available in form A, B, C, D, or E, up to a maximum of 6 Poles.

All Advance Telephone Relays feature small size, short armature travel, and highly efficient magnetic structure. In addition to the type TQ "Miniature" telephone relay (illustrated), which has a contact rating of 3 amps resistive, Advance also offers the TF "Midget" the TD "Small" and the TS "Sensitive." All with a contact rating of 5 amps.

Available From Leading Distributors

WRITE FOR COMPLETE DETAILS

You'll want all 4 data sheets for your file: TQ, TF, TD & TS.

ADVANCE RELAYS

ADVANCE RELAYS

ELGIN

A PRODUCT OF ELECTRONICS DIVISION
ELGIN NATIONAL WATCH COMPANY

Dept. F, 2435 N. Naomi St., Burbank, California

WHAT'S NEW

Remington-Rand Div. of Sperry Rand Corp. (Kenneth R. Herman), Electronic Signal Co., Inc. (Bernard J. Jacobson), Conoflow Corp. (M. Mark Watkins), and Philips Electronics, Inc. (Arie Vernes).

Eppert, executive vice-president since 1951, succeeds the late John S. Coleman. Haggerty, who replaces J. E. Jonsson, elected chairman of the board, was the man most responsible for diversifying TI's interests when it was mainly concerned with geophysical exploration for oil. He has been executive vice-president since 1951. Herman was a top executive with Vickers, Inc., only a short while ago; for the past few months he has been executive vice-president of Sperry Rand.

Jacobson was formerly vice-president and general manager of Electronic Signal, manufacturer of toll collection systems, truck weighing devices, highway traffic computing systems, and other electronic control equipment. Watkins succeeds R. B. Werey, and is in turn succeeded, as executive vice-president, by John C. Koch, vice-president and general manager. Vernes, formerly senior vice-president, succeeds Pieter van den Berg, who advances to chairman of the board.

Other Important Moves

Varo Mfg. Co., Garland, Tex., has a new chief engineer and a new director of advanced engineering. They are, in that order: **D. Ray Taylor,** who was with Minneapolis-Honeywell and Schuttig & Co. before joining Varo three years ago; and **Winston O. Faith,** formerly with Temco Aircraft and Chance Vought, where he worked with automatic controls, particularly servomechanisms.

Edward I. Brown, formerly chief engineer at the Torrance (Calif.) plant of Vickers' Aero Hydraulic Div., has been named director of engineering for the Machinery Hydraulics Div. His appointment coincides with that of Gordon H. Clayton, who comes from Power Equipment Co. as general manager of the Electric Products Div.

Tele-Dynamics, Inc. has named **Herman Epstein,** formerly manager of the Digital Communications Dept. of the Burroughs Research Center, vice-president for engineering. In 1956 Epstein won the IRE award for the most creative contribution to computer art.

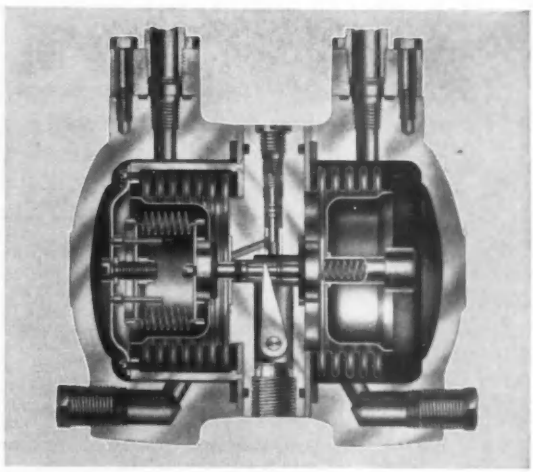
Neal J. Dean, a specialist in the

NEW!

Honeywell Bellows Meter...

unequalled for accuracy, stability, versatility in flow and liquid level metering

The new Honeywell Bellows Flow Meter gives the better performance demanded by its potential users. It's the most advanced meter body available today, with important advantages never before found in flow and liquid level meters.



Some of its outstanding features:

Sensitive and accurate—Sensitive to within 0.05% of full scale ... calibrated accuracy ±0.5% of full scale.

Leakproof—Between liquid fill and process fluid.

Automatically stabilized—Changes in meter body temperature or static pressure have no effect on output shaft position. The Honeywell Bellows Meter operates efficiently in surrounding temperatures of minus 40°F to plus 250°F.

Unmatched convenience features—Including fast range changing in the field ... connections for both horizontal and vertical piping ... quick calibration and adjustment ... easy cleaning and servicing.

High corrosion resistance—Seamless, stainless steel formed bellows give long, trouble-free service with virtually all process fluids.

Fast, effective damping adjustment—New type pulsation check with rectangular orifice enables essentially linear damping adjustment ... and you can adjust from outside the meter body during operation.

Models are available in many ranges, for both flow and liquid level measurement and control. Get details on *all* the features of the new Honeywell Bellows Meter by calling your nearby Honeywell field engineer today ... he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

REFERENCE DATA: Catalog C22-1

Honeywell

First in Controls

New COX Flow Indicator

2% Accuracy

Type 7A

The Cox Flow Indicator provides a dramatic new dimension in direct reading instrumentation. Where accuracy and reliability are essential *at a low initial cost*, the Type 7 is the answer.

The Indicator is for use with Cox turbine flowmeters or other transducers producing a frequency signal directly proportional to flow rate. It is available for readout in either volumetric or gravimetric units—with specific gravity adjustment. A span adjustment enables the Indicator to be calibrated to any particular transducer. Panel and portable models are available.

A second model not shown, the Type 7B, provides accuracy of 1% of flow.

We welcome the opportunity to demonstrate the Type 7 Indicator to you, without cost or obligation, to prove its superior features. *Cox Instruments Division, George L. Nankervis Company, 15200 Fullerton Avenue, Detroit 27, Michigan.*

A new bulletin describing the Type 7 Indicator is available. Ask for Bulletin No. 900

Cox Instruments

Precision Instruments Since 1912

WHAT'S NEW

automation of bank operations, has left Ramo-Wooldridge, where he was director of data processing consulting, to become director of EDP for the central region of Booz, Allen & Hamilton, management consultants. Dean has also been with Laboratory for Electronics, Sonotone Corp., and Columbia University's Electrical Measurements Laboratory.

L. C. Schaefer, the new vice-president for engineering for Torq Engineered Products, Inc., was formerly engineering manager of Westinghouse's Industrial Motor Dept.

The Wurlitzer Co. has brought in an electronic specialist as manager of engineering and research, to apply his talents to the company's civilian and government projects. He is **A. Donald Arsem,** most recently manager of engineering and research for Stewart-Warner Electronics. Before that he was with GE, first as head of the Missile Guidance Section, then as head of the Magnetic Materials Application Section, and finally as manager of advanced product development in the Electronics Laboratory.

William A. Stevenson has moved from Convair, where he was chief engineer of the advanced missile projects, to Lockheed, where he will direct design of the structural and internal systems of the Polaris missile. His official title: assistant division manager for missile design. Stevenson joined Convair in 1950. He holds degrees in mechanical engineering, electrical engineering, and business administration.

Owen J. Ott, formerly with Boeing Airplane Co. and Electro-Mechanical Research Corp., has been named senior research engineer and group leader on airborne telemetry by the new Data-Control Systems, Inc. (CtE, Feb., p. 169). At the same time **William A. Whitbeck** joins DCS as manager of manufacturing.

New supervisors at Shell Development Co.'s Emeryville (Calif.) Research Center are: **R. P. Bell** (Computation Laboratory), **P. Stillson** (operations research and statistics in the Applied Mathematics Dept.), **J. F. Fidiam** (design engineering and manufacturing in the Instrumentation Dept.), and **D. B. Caples** (computer maintenance).

Obituary

Ludwig Arnson, 75, retired chairman and president of Radio Receptor Co., Inc. of Brooklyn, N. Y.; at his home in New York City.

Adjusting grinding speed is a simple twist-of-the-wrist with Cleveland Speed Variator

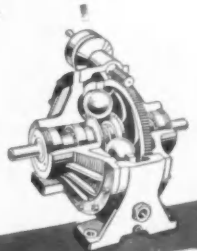
Curtis Machine Division, The Carborundum Company's Contact Wheels and Rolls used with abrasive belts for polishing and precision grinding, must themsevles be ground to tolerances and balance . . . at the precise speed HP for the specific application.

Cleveland Speed Variator, with continuous speed progressions over its full 9:1 range, provides the necessary changes of speed instantly, smoothly. Variator can be adjusted manually or by remote control.

If speed variation is important in your operations, now's the time to learn more about Variator. Send today for Bulletin K-200.

The Cleveland Worm & Gear Company, Speed Variator Division, 3260 East 80th St., Cleveland 4, Ohio.

Sales representatives in all major industrial markets.
In Canada: Peacock Brothers Limited.



HOW IT WORKS

Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts. Relative speeds of the shafts are adjusted by changing the positioning of the axles on which the balls rotate (see cutaway view, right).

CLEVELAND SPEED VARIATOR

Never before such capacity in so small

New Adlake little giant

packs 75 amps. into
$4^{23}/_{32}'' \times 2^{1}/_{16}'' \times 2^{3}/_{16}''$

Here is exceptionally high interrupting capacity in the smallest bulk ever achieved—an ingenious design tested and built to serve indefinitely.

Scaled down in everything but performance, all the notable values of Adlake mercury-to-mercury relays are here, including a molded coil, impervious to time and usage.

The Little Giant, Type 1141, offers the long-proved advantages of Adlake design and construction: Perfect snap action without burning, pitting or sticking . . . fixed, tamper-proof time delay characteristics . . . protection from dust, dirt, and moisture in a hermetically sealed case . . . quiet, chatterless operation. Like all the dependable Adlake relays, Type 1141 will require no maintenance.

Our engineers will be happy to help you with your control problems — no obligation. Write The Adams & Westlake Company, 1181 North Michigan, Elkhart, Indiana.

The Adams & Westlake Company

New York . . . ELKHART, INDIANA . . . Chicago

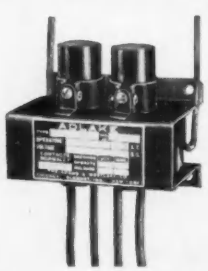
Original and Largest Manufacturer of Plunger-type Relays

Established 1857

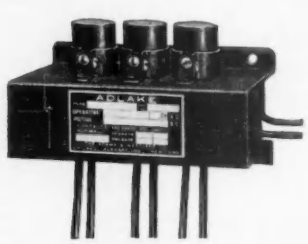
Four Popular Models from Adlake's Complete Line

Type 1140

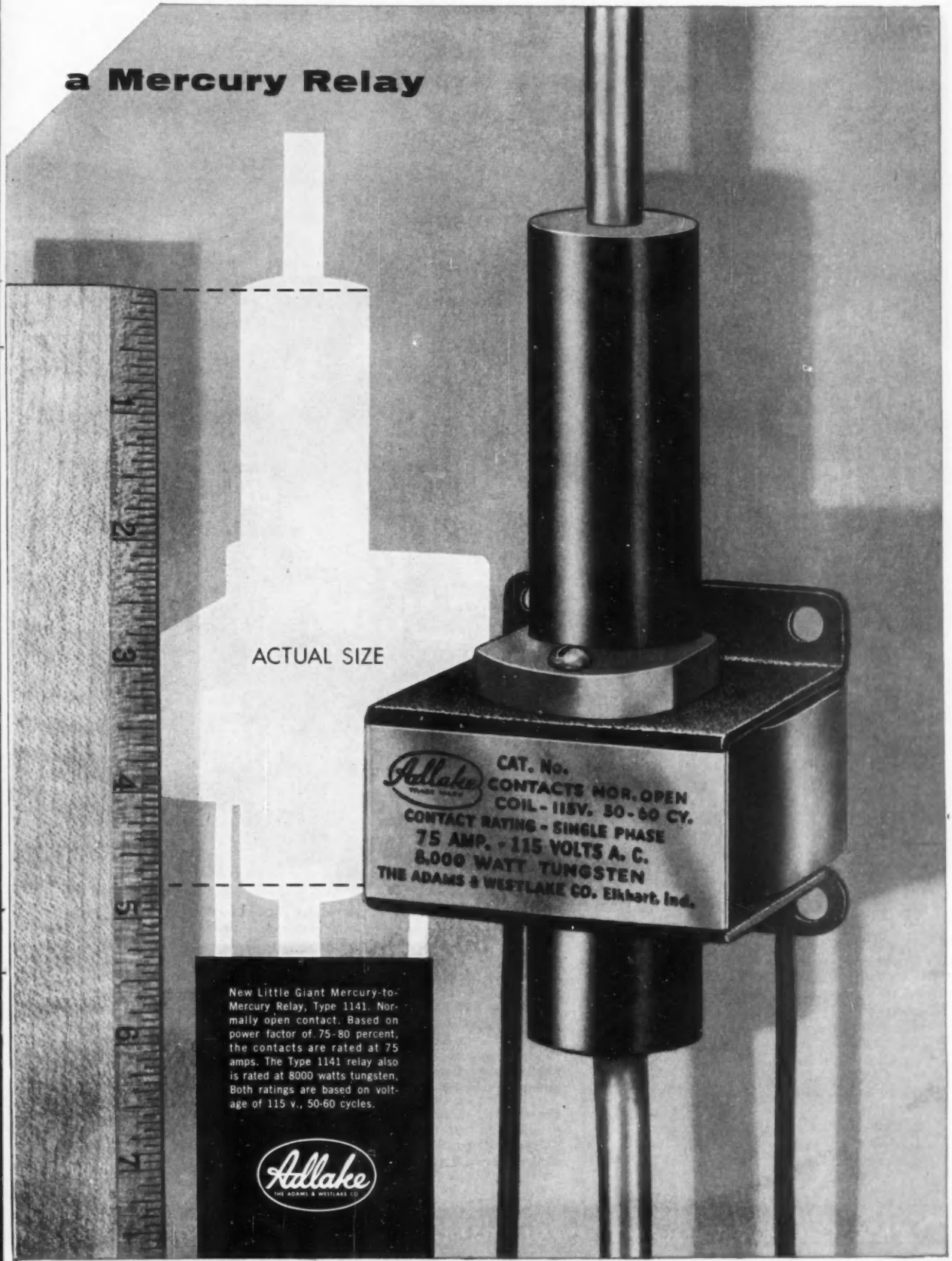
Type 1101



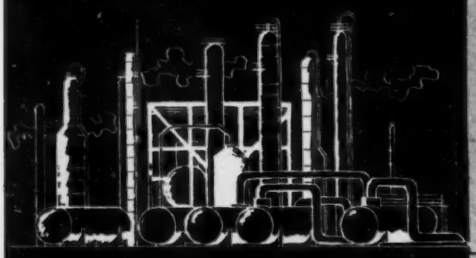
Type 1123



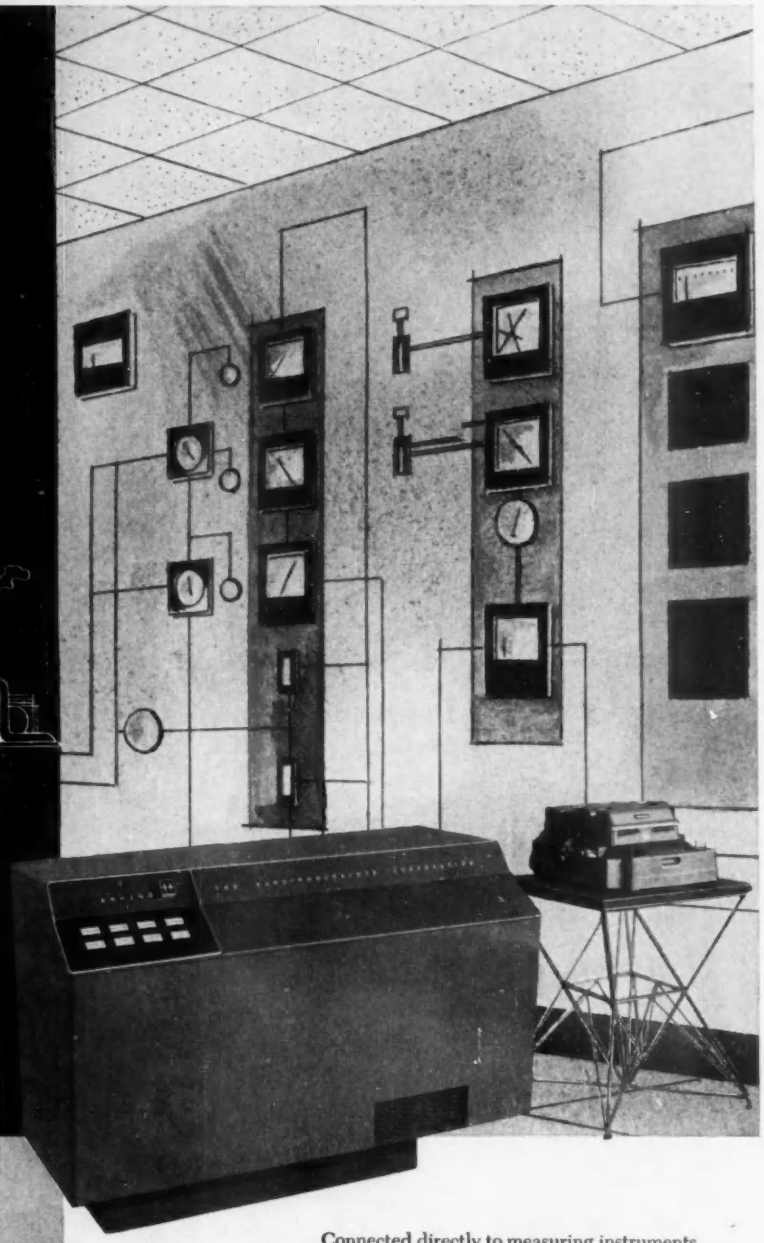
Type 1133


a Mercury Relay
ACTUAL SIZE
Adlake
CAT. No.
CONTACTS NOR. OPEN
COIL - 115V. 50-60 CY.
CONTACT RATING - SINGLE PHASE
75 AMP. - 115 VOLTS A. C.
8,000 WATT TUNGSTEN
THE ADAMS & WESTLAKE CO. Elkhart, Ind.
New Little Giant Mercury-to-Mercury Relay, Type 1141. Normally open contact. Based on power factor of 75-80 percent, the contacts are rated at 75 amps. The Type 1141 relay also is rated at 8000 watts tungsten. Both ratings are based on voltage of 115 v., 50-60 cycles.
Adlake
THE ADAMS & WESTLAKE CO.

advanced data logging



...with the RW-300 digital control computer



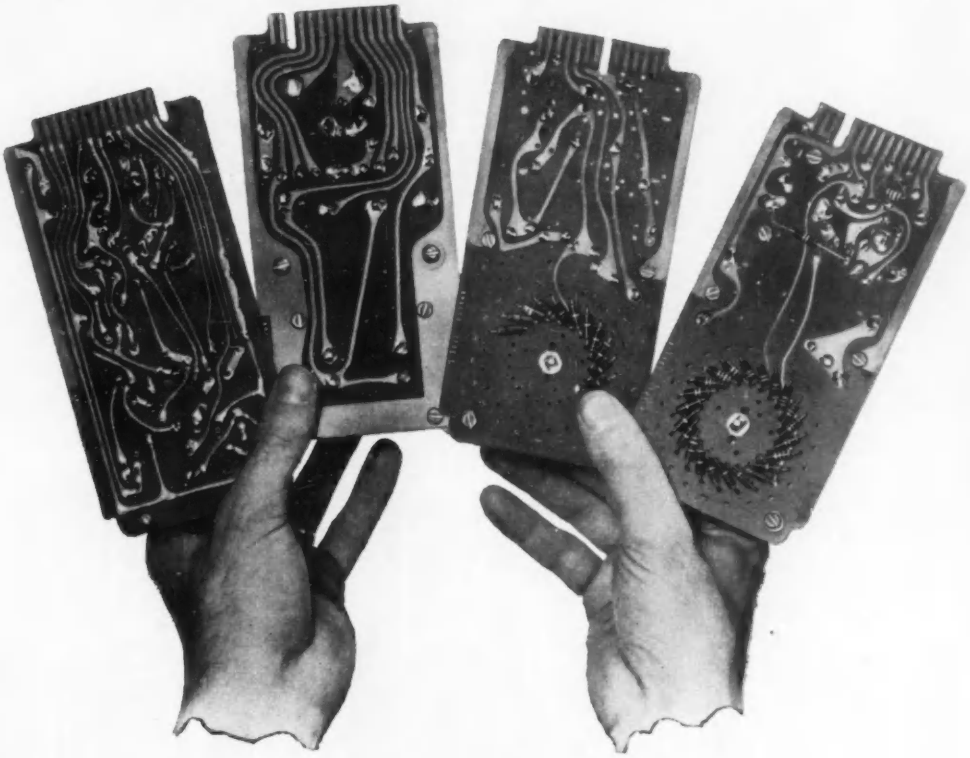
The Ramo-Wooldridge RW-300 Digital Control Computer—the first digital computer designed specifically for automatic on-line process control and data logging—offers significant advantages as the heart of advanced data logging and scanning systems for oil refining, chemical, and other process industries. Unlike conventional data loggers, the RW-300 can be converted to completely automatic control through a minor field modification without purchasing expensive additional equipment and without scrapping any part of the existing logger.

Connected directly to measuring instruments, the RW-300 can do more than log raw or partially processed data. It can also compute and immediately print out more meaningful information such as yields, conversion efficiencies, and energy balances. The RW-300 can also calculate operating guides for plant personnel to follow. In addition to checking process variables against upper and lower limits, the RW-300 can perform more sophisticated checks on process equipment and the process itself. These checks reduce plant maintenance costs by detecting faulty operation of the process in time for corrective action.

For technical information on automatic process control and advanced data logging with the RW-300, write: Director of Marketing, The Thompson-Ramo-Wooldridge Products Company, P. O. Box 45067, Airport Station, Los Angeles 45, California, or call OSborne 5-4601.

THE THOMPSON-RAMO-WOOLDRIDGE PRODUCTS COMPANY

SWARTWOUT AutroniC® INSTRUMENTATION



- - - the process controller with CARD SENSE

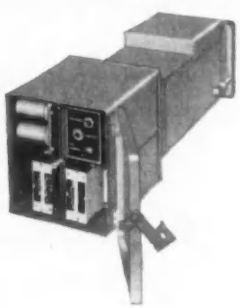
Here you see the entire inner-workings of the AutroniC Process Controller. They consist of just four printed circuit cards.

These cards make good sense to the instrument and process engineer. They can be interchanged in seconds to revise the control function; or they can be replaced to avoid "in-the-line" check-out of equipment. They simplify maintenance. No wire need ever be disconnected. Every functional section plugs in, pulls out . . . with positive, protective interlocks which prevent inadvertent process upsets.

The AutroniC Controller is the only fully electronic, completely non-mechanical control unit available. Thus, it offers you the fullest utilization of advantages inherent to electronic systems. Signal lag doesn't exist. Sensitivity is limitless. And, control performance is correspondingly improved.

Right now, major concerns in many industries are putting their processes years ahead with AutroniC Instrumentation.

Four new bulletins describe the Unitized AutroniC System. Request Bulletin Series A-801.



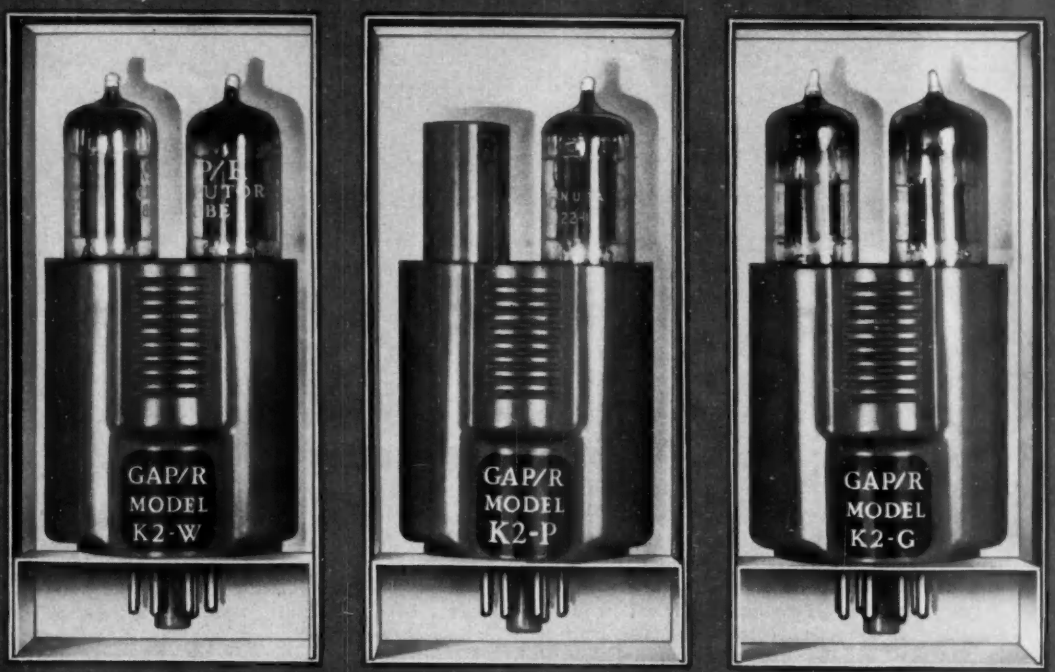
SWARTWOUT

. . . world leader in electronic process instrumentation

THE SWARTWOUT COMPANY
18511 EUCLID AVENUE,
CLEVELAND 12, OHIO

S.A. 1052

PLUG FOR ANALOG



FAST DC AMPLIFIER: Model K2-W is an efficient and foolproof high-gain operational unit for all feedback computations, fast and slow. A number of special varieties are also in quantity production. **($24.00)**

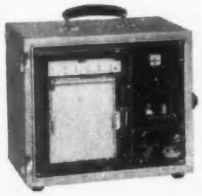
SLOW DC AMPLIFIER: Model K2-P offers long-term sub-millivolt stability, either by itself or in tandem with the K2-W. High-impedance chopper-modulated input. Filtered output to drive balancing grid or follower. **($60.00)**

SERRASSOID GENERATOR: Model K2-G produces a fixed triangular wave of 100 V peak-peak, at 500 kcps. Use it for quadratic rounding in diode networks, and for many other non-linear recreations. **($29.00)**

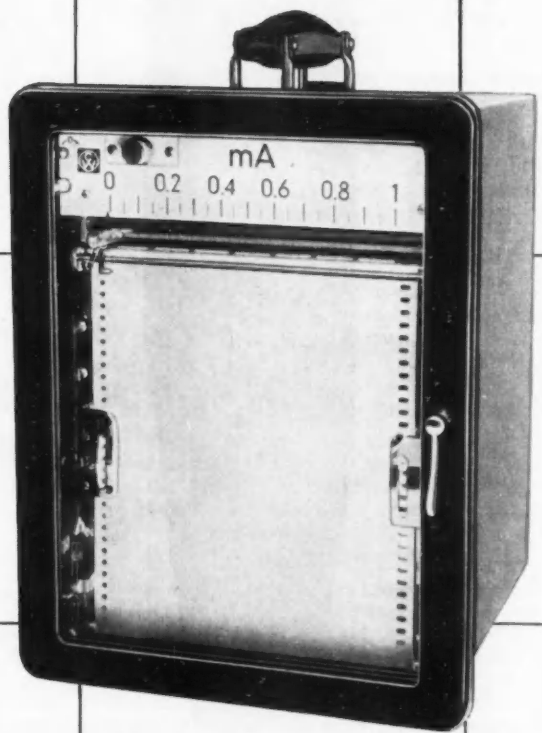
PHILBRICK uses these octal plug-in modules, and many others like them in their standard computing instruments. They are tried and true, compact, convenient, and economical. You too can find profit and happiness with their help . . . . . *All K2 Plug-ins run on plus and minus 300 VDC and 6.3 VAC. Socket wiring is simple and standardized. Write for freely given opinions on your application.*

The analog way is the model way . . . . . GEORGE A. **PHILBRICK** RESEARCHES, INC.

227 Congress St., Boston 10, Massachusetts

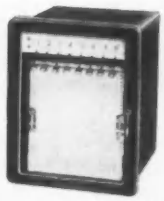


Millivolt Recorder with self-balancing DC amplifier. 2-5-10-20—50-100-200 mv ranges. 1.5% accuracy except 2mv range (2%.)

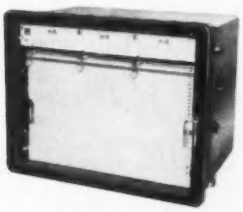


Strip Chart Recorder, standard model 81 (portable) and 82 (flush) are also available for wall and projection mounting. Weighs only 19 lbs. and measures 7½" x 9⅞" x 8½".

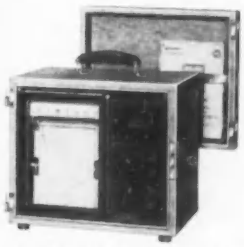
$445.00



Operations Recorders with 4, 8 or 16 pens which register independently the on-off time of machinery. Each track can be a different ink color.

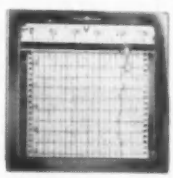


Double size recorder models, take up to six multiple, independent movements. Wall and projection mount available.



Universal AC-DC Recorder with total of 23 ranges. Complete in solid oak case, 13¾" x 11¾" x11" . . . weighs 36 lbs.

Miniature Slim Recorder model saves half the width of standard recorders. Only 3 13/16" x 7½" x 8⅝".



Miniature Square Model Recorder, in flush mount, 5 11/16" square x 13" deep.

Announcing

Curtiss-Wright RECTILINEAR STRIP CHART RECORDERS

Curtiss-Wright recorders, DC preamplifiers, and controllers, can be combined into systems to meet varied demands.

Backed by a leading West German maker's **50 YEARS** of precision instrument manufacturing

A rare combination of precision and ruggedness . . . straightforward in design and simple to operate . . . these new Curtiss-Wright precision instruments are made through a licensing agreement with Metrawatt AG, one of the most experienced of West German precision instrument makers.

Important features include: *Rectilinear Recording • Inkless and Ink Recording in One Unit • Three-Speed Transmission plus 60:1 Speed Change • 1% Accuracy • Shock, splash and dustproof.* The complete line includes double size and miniature sizes; AC, DC, power and combination movements; wide choice of ranges and chart drives. Write for full information.

ELECTRONICS DIVISION

CURTISS-WRIGHT

CORPORATION • CARLSTADT, N. J.

ARMA'S SECRET WEAPON

Bug hunting . . . failure testing . . . safety factors . . . flight testing—none of these traditional reliability concepts is sufficient to insure maximum performance of missile guidance systems.

We use them all at Arma—but the designer's pencil is our "secret weapon." For true reliability must originate at the design stage—and then be implemented by a full-scale quality control and reliability program. ARMA . . . Garden City, N. Y. A division of American Bosch Arma Corporation.

4921

AMERICAN BOSCH ARMA CORPORATION

ONLY
KIN TEL DIGITAL
VOLTMETERS
GIVE YOU
ALL THESE
ADVANTAGES FOR
ONLY $2100

1. SINGLE-PLANE READOUT: KIN TEL digital voltmeters employ a simple projection system to present numbers on a readable single plane...no superimposed outlines of "off" digits...reduced possibility of error. Standard lamps give 7000 to 8000 hours of life, compared with 100 to 200 hours for ordinary readouts.

2. COMPLETE LINE OF ACCESSORIES—SPECIAL SYSTEMS: Versatile "digital building blocks" permit measurement of AC, ohms, ratios of AC and DC, automatic scanning of multiple inputs. Preamplifiers increase digital voltmeter sensitivity to 1 microvolt DC, 10 microvolts AC. Buffers permit driving typewriters, tape punches and printers. KIN TEL's Special Products Department can design and manufacture digital instruments to meet your special requirements . . . complete digital systems for data logging, missile checkout and automatic production line testing.

3. ADVANCED CIRCUIT DESIGN: Transistors employed where they contribute to performance and reliability...relay drive coils energized with DC as in telephone type service to provide long, trouble-free operation...automatic, continuous standard cell calibration. No electronic circuitry in readout allows easy remote mounting. Sensitivity control permits stable reading of noisy signals.

4. MANUFACTURING EXPERIENCE: KIN TEL has manufactured over 10,000 "standard cell accuracy" DC instruments on a true production line basis. Only by this method, by years of repeated manufacturing experience, by an over-all awareness of the accuracies and tolerances involved, is it possible to guarantee consistent accuracy and reliability...to assure real value for every dollar you invest.

5. NATIONWIDE APPLICATION ENGINEERING FACILITIES: KIN TEL has engineering representatives in every major city. An experienced staff of over 200 field engineers is always immediately available to help solve your application problems, provide technical data, or prepare a detailed proposal. Factory level service is available in all areas.

+·7895

6. DESIDERATE SPECIFICATIONS (MODEL 401 DC DIGITAL VOLTMETER):

Display...Four (4) digit with automatic polarity indication and decimal placement. Total display area 2" high x 7½" long, internally illuminated. Individual digits 1⅛" high.

Automatic Ranges...0.0001 to 999.9 volts covered in four ranges. Sensitivity control provides least digit sensitivities of .1, 1, and 10 mv.

Accuracy...0.01% ±1 digit.

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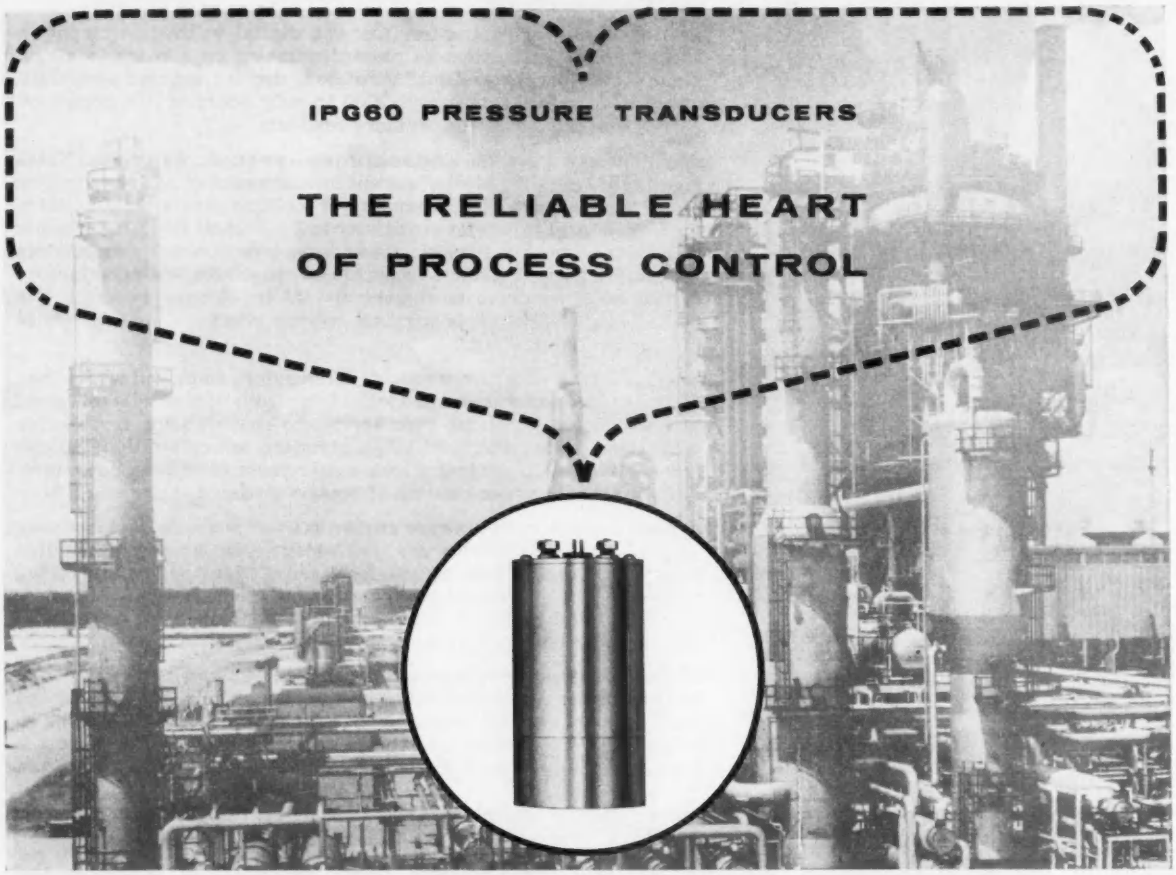

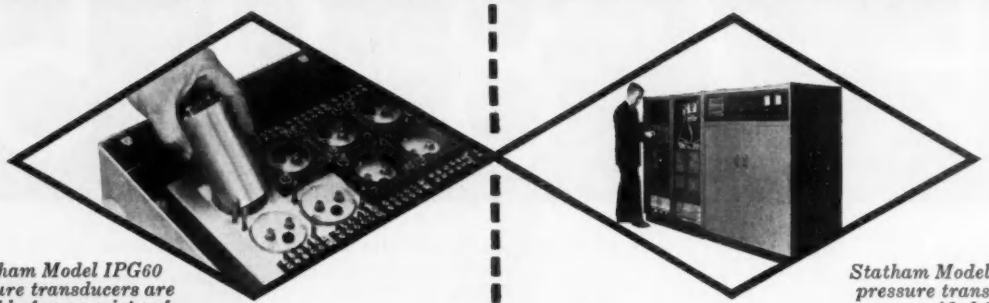

Statham Model IPG60 pressure transducers are suitable for a variety of applications requiring accurate pressure measurements.

Statham Model IPG60 pressure transducers are specified for the Beckman 112 Data Processing Computer.

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PRESSURE MEDIA: Non-corrosive fluids

Statham

RANGE: 0 to +15 psig.
NON-LINEARITY & HYSTERESIS: Not more than ±0.25% of full scale

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2-way and 3-way Manual Reset

3-way Fully Automatic

ASCO offers a complete selection of corrosion-resistant 2 and 3-way solenoid valves

ASCO is the single source for a complete selection of Solenoid Valves capable of controlling corrosive gases and liquids.

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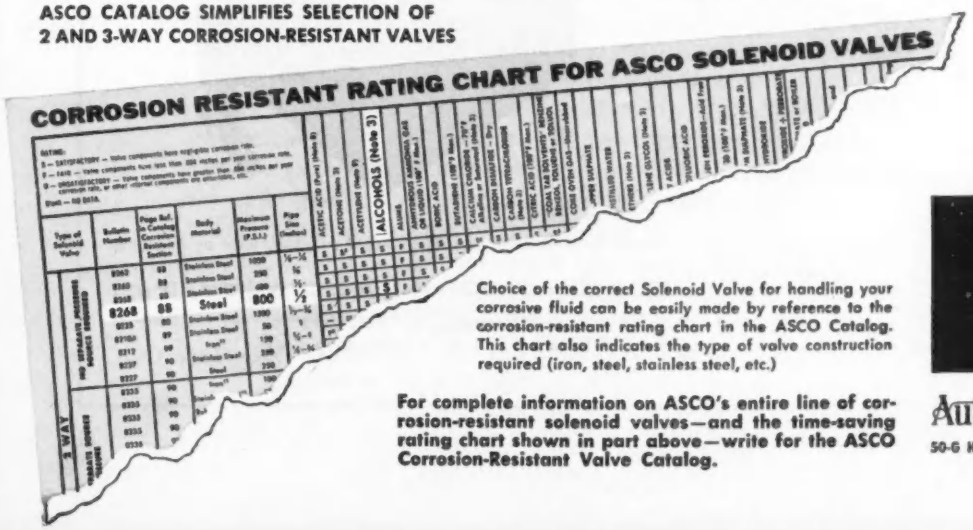
CORROSION RESISTANT RATING CHART FOR ASCO SOLENOID VALVES



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For complete information on ASCO's entire line of corrosion-resistant solenoid valves—and the time-saving rating chart shown in part above—write for the ASCO Corrosion-Resistant Valve Catalog.

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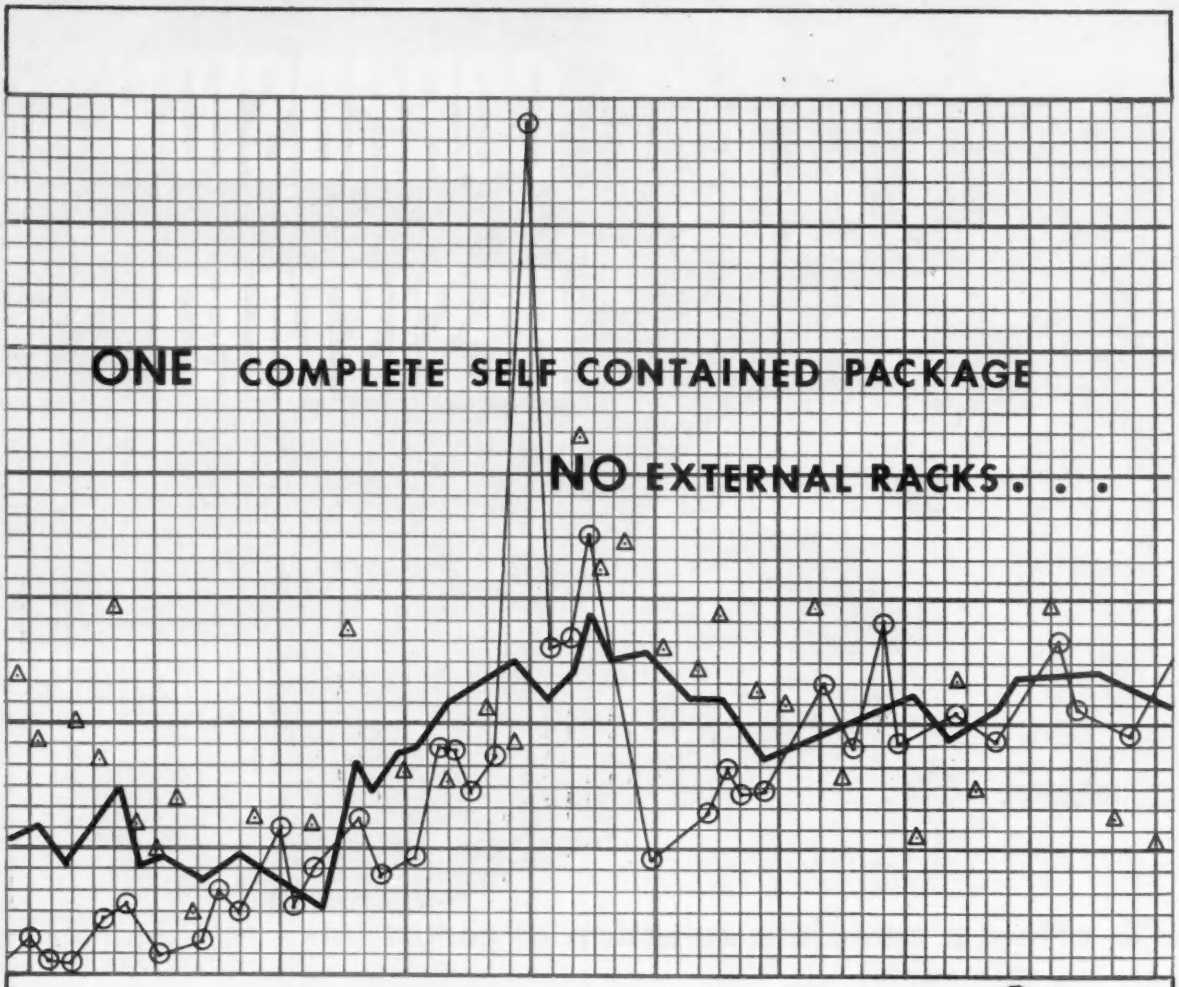

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Productivity: Warehousing, Figures, and Meetings.

There will be a completely automatic warehouse in the U.S. within two years. So says material handling consultant Irving Footlik in Chicago. The technology is here today; the big problem is justifying an installation economically.

The automatic warehouse

A lot of big names are studying the completely automatic warehouse. For example, IBM prepared one proposal for a cosmetic company (rejected because of high price), is currently at work on a study for a large soap and drug manufacturer. General Electric Co. has been pushing the systems concept to warehousing, primarily for use by that company's own divisions. Food Machinery & Chemical Co. has also adopted the systems approach, would like to apply it in the food industry plants. Two recent newcomers in the field are Stewart-Warner Electronics (see page 21) and Pesco Products Div. of Borg-Warner Corp.

Among the smaller companies, Industrial Electronic Engineers is one of the leading figures. Its automatic order-picking machine (CtE, Mar. '57, p. 20) is probably the most sophisticated application of automatic warehousing at work in the U.S. IEE has had a lot of inquiries but no more concrete sales for its machines. In New York City, Dasal Corp. has concentrated on automatic warehousing for retail stores. The company has one big installation at a department store, using a special-purpose computer—the DASAC.

At the Lamson Corp., a warehousing equipment builder, Vice-President H. C. Keller says that automatic warehousing will be accepted just as soon as warehousing labor costs rise enough to make it economical. In the meantime companies are making the warehouse automatic a little at a time. Automatic equipment that is appearing: palletizers to take cases from a conveyor line and put them on pallets, automatic depalletizers to perform the reverse operation, automatic stackers and destackers, photoelectric cells for identifying products so they can be automatically switched to different conveyors, and tow carts guided by a wire buried in the warehouse floor.

The minimum price tag currently put on an automatic warehousing system is $200,000 for a moderately large installation. And that would be limited to handling less than 200 items. To try to get the cost down, equipment manufacturers are doing some experimenting. For example, The Paulson-Lathrop Co.

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Universal Chopper-Stabilized Amplifier

Open-loop gain of this operational amplifier drops at 6 db/octave over entire working range.

This feature enables the user to shape the response from DC to well above 100 KC by means of feedback to meet nearly any application.

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The amplifier is manufactured by George A. Philbrick Researches, Inc., Boston 10, Massachusetts. The chopper, naturally, is by Airpax.

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Cambridge Division, Jacktown Road, Cambridge, Maryland

CHARACTERISTICS OF TYPE 175 CHOPPER

Airpax 60-CPS chopper Type 175 is a miniature unit with permanently adjusted SPDT BBM contacts.

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Frequency	60 ±3 CPS
Voltage	6.3 ±0.6 RMS volts

CONTACTS

Dwell Time	167 ±10 electrical deg.
Balance	within 15 electrical deg.
Phase Angle	20 ±5 electrical deg.
Voltage	up to 100 DC volts
Current	up to 2 MA
Noise	50 microvolts average

Hermetically sealed for trouble-free operation in any atmosphere; internal mechanism rigidly mounted to withstand shock and vibration encountered in portable equipment.

AIRPAX
DESIGNERS ENGINEERS

converted its automatic stacker from electronic control to mechanical control using a limit switch and a magnetic clutch, cut the cost from over $5,000 to under $3,000.

Productivity figures

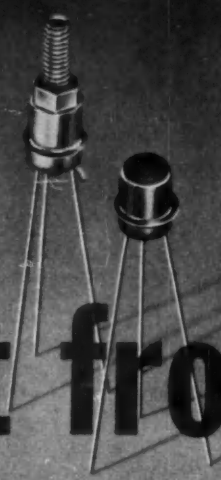
How good are productivity figures? That's a question that's likely to come up after a company has installed a lot of automatic equipment. Right now labor negotiations in Detroit have spotlighted productivity increases. And wage hikes will undoubtedly be tied to these gains. That shows how important these figures are. Yet, General Motors figures the rise in productivity in the auto industry at 2.5 percent per year, while the United Auto Workers says it's 3.9 percent.

One of the key sources of such data is the U. S. Dept. of Labor's Bureau of Labor Statistics. But Ewen Clague, BLS Commission of Labor Statistics, won't be drawn into the argument. He says that BLS doesn't consider its auto industry figures accurate enough to release separately. (He puts the productivity increase for all manufacturing at 3.4 percent.)

Clague's comments on this and other indices should serve as a warning to people who rely on them too heavily. For one thing, he's really worried over the fact that monthly changes in his consumer index causes "billions of dollars to change hands" (because of the many labor contracts that now include cost-of-living clauses). He says, "My figures are good but they aren't that good."

The BLS commissioner cites auto prices as an example. He uses actual prices instead of list. That sets up an artificial drop in prices in September (when dealers are cleaning out last year's models) and an equally false rise in November (after dealers introduce new models and keep discounts to a minimum). And the only auto prices used are Ford, Chevrolet, and Plymouth.

Technical meetings are having their problems attendance-wise this year. Figures are falling way below expectations. Back in January, the Fourth National Symposium on Reliability and Quality Control expected 1,500 visitors, but only 1,000 showed up. In April two more meetings suffered similar fates. The Automatic Techniques Conference in Detroit planned for 500 attendees, but registered only 197. During the same week, the technical meetings at the Design Engineering Show were geared for an audience of 1,500, but only 1,000 attended. The question bothering society leaders: is the drop in attendance caused by the economic recession or by too many meetings with mediocre technical programs?



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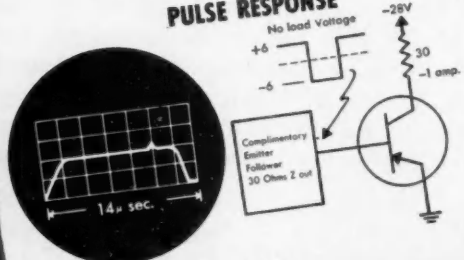

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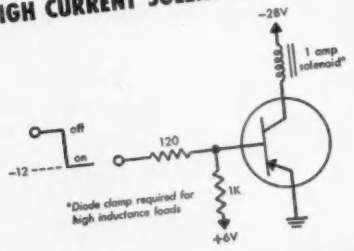

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Control ENGINEERING

JUNE 1958

Keep Technical Education Off the Dole

Technical education is expensive. This is no news to practicing engineers who have graduated from technical colleges and universities during the last two decades. But it's still hard to accept in view of the fact that the expense is only a fraction of the true cost of these engineers' education: their tuitions paid for less than half of the costs of teachers' salaries and operating education plants. And because the whole operation would have been in the red anyway, had it not been for philanthropies and hidden subsidies, we can understand why the colleges and universities were unable to develop surpluses. Now, without surpluses, they cannot finance re-education of educators and construction of new plant.

Inadequate plant capacity, technically obsolete faculty, and underpaid faculty will be overcome only by money. The College Housing Loan Program that released $250 million of long-term loans for new dormitories in 1957 helps. Government research contracts and grants to the tune of a half-billion dollars per year support research that parallels and stimulates technical education. That is, they stimulate educators into brushing up or completely renovating their technical knowhow, but they do not, in general, pay at a rate that meets the full overhead on the educational plant. Naturally, then, they do not help in the accumulation of funds for future expansion and technical updating.

The Federal government is well-advised to consider this an emergency, regardless of Sputniks and Explorers, and to enact emergency measures. Three major education bills—Hill-Elliott, Murray-Metcalf, and the Administration's—proposed scholarships, student counseling, improvement of science teaching in elementary and secondary schools, and improvement of science facilities in colleges and universities. We cannot overemphasize that these should be considered emergency measures. Still, none of them will be able to close the gap for more than four or five years.

The real solution is to put technical education on an actual-cost basis and to spread the cost out over 10 to 15 years. Loans spread this cost (the Administration's bill proposes 2 percent loans to students and a system that would not require repayment of a cent of principal ($4,000 max) or interest if the graduate puts in a required period of teaching), but do not go far enough. Income tax deductions for both current and future education go much farther. On April 5, the Internal Revenue Service took a small step in this direction in issuing Regulation TD 6291, which permits employees to deduct money spent for education to improve their skills. The giant step that the American Council for Education is trying to sell is—deductions for savings bonds purchased for future education of dependents. If this could be approved now, parents would have a chance to prepare for educational costs while the emergency measures are in effect. Educational changes could be on a business-like scale and education would not go on the dole.

W. E. Vannah

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-*hp*- 500B Electronic Frequency Meter

Model 500B is a rugged, precision instrument widely used for direct-reading laboratory or production line measurements of ac frequency from 3 cps to 100 KC. With -*hp*- 508A-D Tachometer Generators or -*hp*- 506A Optical Tachometer Pickup, the 500B also provides direct tachometry readings.

Typical applications include rf signal beat frequency comparisons, crystal frequency deviations, audio frequency and FM measurements, oscillator stability, machinery rotational speed, average frequency of random events, checking vibration or torsion in gear trains, etc.

Model 500B has an expanded scale feature permitting any 10% or 30% of selected range to be viewed full scale. It also offers a pulse output synchronous with an input pulse for measuring FM components of input signals or syncing a stroboscope or oscilloscope. Readings are independent of line voltage, input signal or vacuum tube variations. $285.00.

-*hp*- 500C Electronic Tachometer Indicator

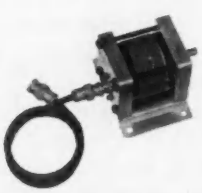
Model 500C is identical to 500B except for meter calibration which is in rpm for greater convenience in tachometry measurements. With appropriate -*hp*- transducers (506A or 508A-D series), -*hp*- 500C will measure rpm from 15 to 6,000,000 rpm in 9 ranges. $285.00.

-*hp*- Rotational Speed Transducers

NO MECHANICAL CONNECTION

-hp- 506A Optical Tachometer Pickup measures speeds 300 to 300,000 rpm of moving parts which have small energy or can not be connected mechanically to measuring devices. Employing a phototube and operated by reflected-light interruptions from light and dark areas on a shaft, -*hp*- 506A may be used with -*hp*- 500B Electronic Frequency Meter, -*hp*- 500C Electronic Tachometer Indicator, -*hp*- 521A or 521C Electronic Counters, and similar instruments. Output voltage is 1 volt rms minimum into 1 megohm; light source is a 21 candlepower, 6 volt automotive bulb; phototube is Type 1P41. $125.00.

MECHANICAL CONNECTION



-hp- 508A/B/C/D Tachometer Generators are for use with electronic counters or frequency meters in rpm measurements from 15 to 40,000 rpm where direct mechanical connection can be made to the rotating part under measurement. -*hp*- 508A produces 60 output pulses per shaft revolution. When connected to an indicating instrument calibrated in rps, it permits direct readings in rpm. Relationship between output voltage and shaft speed is virtually linear to 5,000 pps, simplifying oscilloscope presentation of shaft speed as a function of time for analyzing clutches, brakes and acceleration rates.

-hp- 508B, C and D are identical to -*hp*- 508A except output is 100, 120 and 360 pulses per revolution respectively, and output voltage peaks at successively slower shaft speeds. -*hp*- 508A, B, C or D, $100.00.

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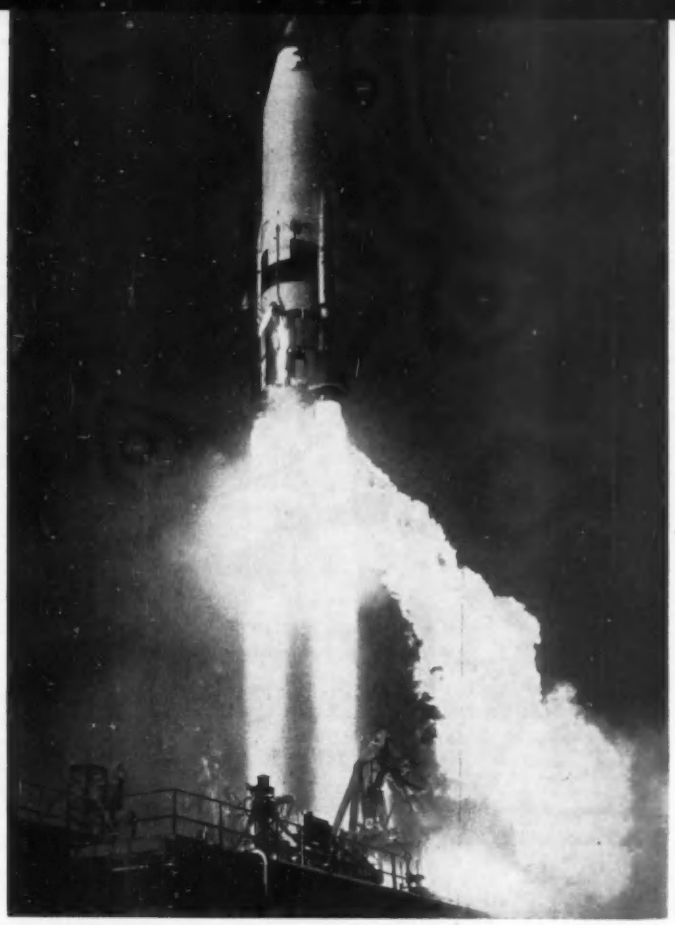
The Air Force Missile Test Center has changed from an aerodynamic to a ballistic range. A Control Engineering editor reports on some of the new technical developments by instrument engineers to test and track ballistic missiles.

LEWIS H. YOUNG
Control Engineering



At Cape Canaveral, Atlas intercontinental ballistic missile starts on the type of trajectory that prompted changes in range instrumentation.

The Change at Cape Canaveral

In the five years since 1953, the Air Force Missile Test Center (AFMTC) in Florida has changed from an aerodynamic to a ballistic range. Five years ago, AFMTC was instrumented to test and track subsonic air-breathing missiles like the Matador. Today the ballistic missile has altered the whole concept of range instrumentation.

Almost everywhere you look you can see the change in AFMTC—at its scientific and logistic headquarters on Patrick Air Force Base, at the missile-launching site on Cape Canaveral (15 miles north of Patrick), and at the down-range stations stretching into the South Atlantic. Some evidence:

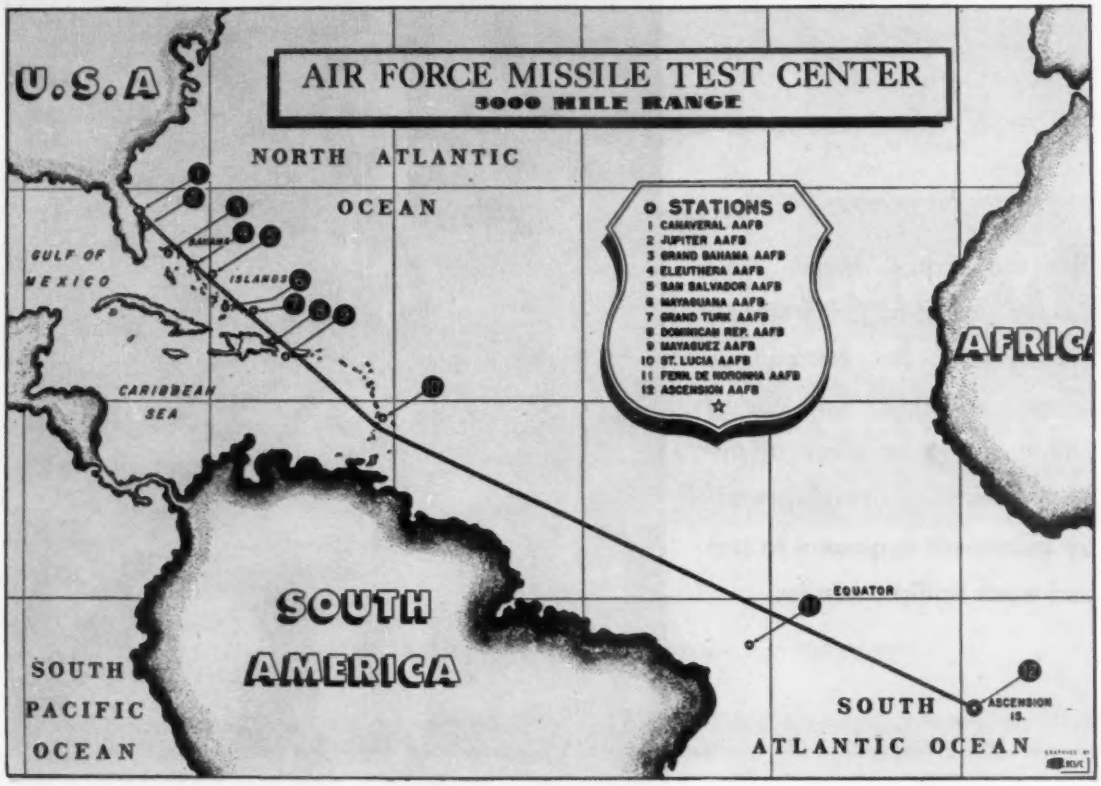
► Investment in range equipment has grown from $75 million in 1953 to $400 million in 1958. And it is still growing. Personnel at AFMTC increased from 7,000 to 16,000 over the same period.

► The range has been extended physically to 5,000 miles from its original 1,200-mile length (see map, next page). Instrumented telemetry ships bridge the 1,600-mile over-water hop from St. Lucia AAFB in the Caribbean to Fern. de Noronha AAFB in the South Atlantic.

► All-weather electronic tracking is slowly replacing optical tracking as a means of obtaining accurate position and velocity data. But optical instruments are playing a new role in providing qualitative engineering information.

► New passive telemetry antennas—with a giant 60-ft diam dish—are obsoleting the small helical antennas that used to be aimed manually.

► Electronic tracking systems have been coupled with a digital computer (an IBM 704) to supply accurate trajectory data on a real-time basis for the first time. One system, the impact predictor, continually tells the range safety officer where a missile will fall at any instant, if it were destroyed at that instant. Another, the apogee predictor, calculates the trajectory of satellite-carrying missiles, tells missilemen how many seconds the carrier is



Map of the AFMTC ballistic range extending over 5,000 miles from Cape Canaveral to the Ascension Islands.

from apogee—the point in space to fire rocket-engine stages that will put the satellite into orbit.

▶ Firing sequencer, which controls the countdown, checkout, and firing, has evolved from a simple device that used to run for 3 min and control 48 functions to a sophisticated plugboard-programmed machine controlling several hundred functions over a 100-min period.

▶ Data-reduction techniques have been improved so that trajectory raw data is being recorded directly in computer format on punched tape, then played into AFMTC's specially designed FLAC (Florida Automatic Computer) data-processing machine.

Behind this drastic switch are the broad differences between the air-breather and the ballistic missile. For example, the ballistic trajectory—flying several hundred miles above the earth's surface at speeds of several thousand mph—makes conventional optical tracking instruments ineffective. The complexity of such a missile demands a considerable increase in the number of powerful telemetry channels to report component functioning during flight. It means more ground line carriers to report how critical subassemblies operate before launching. And, because things happen so fast, more attention to range safety.

Complexity has stretched the test lead time, too. Instrumentation work for a ballistic missile starts almost two years before the missile builder is ready to bring the first unit to Florida for launching. The initial step: the missile contractor prepares a list of variables—and the degree of accuracy associated with each—it feels must be measured.

Receipt of the list sets a procedure in motion involving three groups: the U.S. Air Force, which directs operation of the range, Pan American Airways operating the range as prime contractor to USAF, and RCA Service Co., which engineers and operates range instrumentation as a subcontractor to PAA.

USAF requires that every missile contractor justify his test request. Once the list has been approved, USAF turns it over to PAA, which starts planning logistic support of the test—building new firing pads if needed, new instrument blockhouses, and any remote control facilities.

Right now, for example, PAA is putting the finishing touches to new firing pads and blockhouses for Titan, intercontinental ballistic missile expected to be ready for test this summer. New launching facilities are also being constructed to test the Navy's Polaris, 1,500-mile missile. Polaris' pad will have a computer-controlled mechanism that will simulate the roll of a ship during prelaunching and launching.

PAA passes the list of measurements required on to RCA Service. In its engineering group, RCA first prepares a data acquisition plan. This spells out which measurements can be made with existing instruments and which measurements will require the development of new or refined devices. USAF also reviews the completed acquisition plan. Once the program is approved, RCA puts it into action.

A new role for optics

One technique still required in every data acquisition plan is optical instrumentation. RCA's Gaver M. Powers—an eight-year veteran who started at Patrick as an engineer in the firing and timing group and is now manager of optical engineering—has watched use of optical instruments change. On the aerodynamic range, he recalls, cameras were the backbone for position data. Askania phototheodolites tracked the missile as it flew down-range, supplied the accurate trajectory data required. On the ballistic range, he says, engineers still use three main types of optical instruments:

- Metric optical equipment—instruments from which angular measurements (of elevation and azimuth) may be obtained. This group included phototheodolites, CZR telescopic cameras, and ballistic plate cameras.
- Engineering sequential cameras—devices that measure attitude (roll, pitch, and yaw), primarily to tell qualitatively what happened during the flight.
- Documentary cameras—record a special portion of the test; usually no time signal is recorded.

But the emphasis has shifted. Today, metric optical equipment is used only to obtain position data near the launching area and to calibrate electronic tracking gear. The big demand is for engineering sequential information. New cameras like the Perkin-Elmer ROTI (see photo below, and CtE, Jan '57, p. 123) can photograph high-speed ballistic missiles at distances up to 160 miles—four times the maximum distance possible five years ago.

The prime function of the sequential cameras is to provide a visual record of what went wrong during flight, particularly if the trouble stems from a structural weakness in the missile or a deficiency in control stability. Some of these cameras are focused on one potential trouble spot, such as a bolt or a weld. Others are high-speed cameras whose total participation in the test may last only 2 sec.

Gaver Powers sees future developments in optics moving in two main directions: 1) extending the use and capability of engineering sequence cameras, and 2) reducing the role of metric optical equipment solely to calibrating electronic tracking gear.

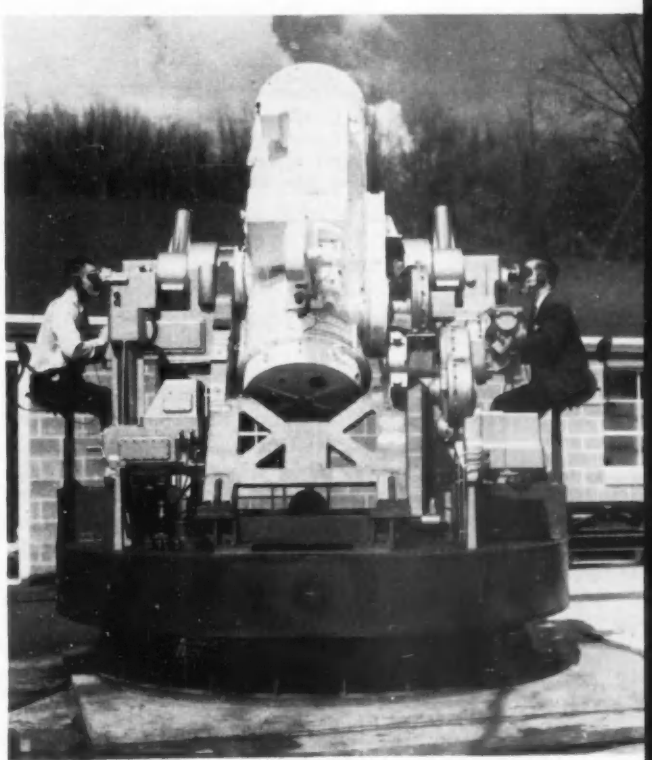
To accomplish this last objective AFMTC is concentrating on improving the ballistic camera, because it supplies the most accurate photographic position data. Operation is simple. The camera is opened before a flight begins; the film then records many images of the missile as it moves in its trajectory. High accuracy results because the plate is calibrated by star photographs recorded on the plate.

But unfortunately, this camera has to be handled like a delicate laboratory instrument. That's a serious limitation on sandy Cape Canaveral. In addition, the film plate must be inserted with an accuracy of a few microns. The camera is usable only during night flights (because of the requirement to get star photographs for calibration). And it can take months to reduce the data.

To overcome such limitations, AFMTC is adopting the techniques of astronomers to evaluate plates. Under development, though still 12 to 18 months away: an interferometer comparator that will reduce ballistic plates automatically to a punched paper tape usable in FLAC. More immediately, camera designs are being refined—a new shutter has been developed to chop the image. Dustproof, stabilized platforms are being erected at the Cape to protect ballistic cameras and to provide additional position rigidity. Optical specialist Powers hopes that this will make a day and night tool out of the ballistic camera.

All-weather electronic tracking

When the first ballistic missile flew down-range at an altitude of several hundred miles, the phototheodolite started losing its importance as a tracking instrument. The high-flying missiles were obviously out of range of these cameras. And what pictures could be taken of the high-speed missiles required bright, clear weather. As a substitute, AFMTC turned to radar, which the range was already using for backup data (though with little precision) and for range safety. Development was pressed on both pulse and continuous wave (CW) radar.



Recording optical tracking instrument (ROTI), set up on Melbourne Beach 30 miles south of Cape Canaveral to supply engineering sequential information on missile tests, demonstrates the trend to long focal length telescopes.

AFMTC has always relied to some extent on pulse radar, using modfied SCR 584 radar sets. These supplied position data by measuring the time required for a radar pulse to strike the missile and rebound to the ground. Two or more sets were used for triangulation. One big advantage: pulse radar techniques need no transponders—transmitters carried in the missile.

Just recently AFMTC has started installing new long-range, high-accuracy pulse radar equipment, the FPS-16. The first units, already installed at Cape Canaveral and at one down-range station, have been coupled with an IBM 704 to produce an effective apogee predictor system for satellite launchings.

Though the accuracy of the FPS-16 is secret, this much can be said: when the Army put Explorer I into orbit, three different tracking systems were used to determine the instant at which the orbiting stages were to be fired from the ground; of the three, data from the FPS-16 radars proved to be the most accurate, so accurate that the FPS-16's are now the backbone of tracking instrumentation used in satellite shoots.

Receivers (in plastic domes) of AZUSA electronic tracking system are laid out along two baselines, perpendicular to each other. AZUSA has been coupled with an IBM 704 computer to predict impact of missiles during tests.

Accuracy of position data supplied by the pulse radars has been improved by equipment that digitizes radar shaft position, putting the data directly onto punched tape. Instead of analog data with its inherent inaccuracy, this equipment supplies angular data with an accuracy of 0.005 deg out of 360 deg. Gianinni & Co. built the first units. The gear turned out two punched tapes, reporting data every half-second. Now AFMTC has an improved transistorized model that can put all data on one tape, ready to be fed right into FLAC. Soon to be installed, the new gear is just half the size of the original digitizing equipment. It's expected to improve reliability by 700 percent.

Study of continuous wave radar has been pushed hard because this technique is a passive one, requires no aiming of antennas. CW operates on the interferometer principle (as does Minitrack, Project Vanguard's satellite tracking system, CtE, Dec. 1957, p. 22). That means a continuous wave signal is transmitted from the missile and received on the ground at several antennas where its phase is compared. The difference in phase—generated by the signal's traveling different distances to the station—indicates the direction of the missile. Direction lines from several stations provide position data by using triangulation techniques.

Electronic engineers Jim Martin and Jerry Schwartz count six tracking systems being used or under study by AFMTC. Two of them are part of the range safety program: DOVAP ELSSE (Doppler Velocity and Position, Electronic Sky Screen Equipment) and Telemetry ELSSE. The remaining four, DOVAP, SECOR, COTAR and AZUSA, are trajectory measuring systems.

Oldest electronic system is DOVAP, developed by the Army at Aberdeen Proving Grounds for use at White Sands Proving Grounds (CtE, Nov. '57, p. 97). DOVAP was brought to Florida when the Army started testing the Redstone missile. It still is considered the most reliable system on the range.

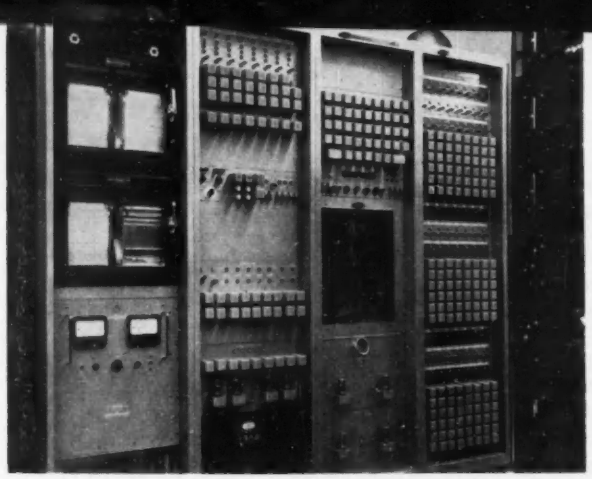
The method has been modified for range safety purposes. To provide information on a real-time basis, the returning signal is modulated so that phase differences cause beats. These beats are converted to position data, which is plotted on "Skyscreen", a grid-covered plotting board. At AFMTC, DOVAP ELSSE is also known as DOVAP-beat-beat.

But DOVAP has some severe limitations. It produces an ambiguous signal that takes time for resolution. Continuity is hard to reconstruct if the signal is lost. And DOVAP signals are subject to flame attentuation, a distortion resulting when the signal passes through the exhaust jet of a missile. These prompted AFMTC to look for new CW systems.

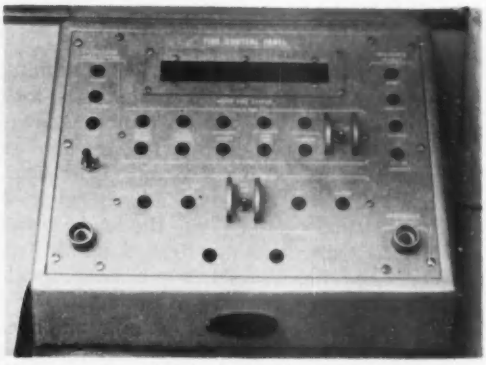
Telemetry ELSSE, SECOR (Sequential Correlation and Ranging) and COTAR (Correlation Tracking and Ranging) were all developed by Cubics Corp. The big advantage of Telemetry ELSSE is that it can use any telemetry signal; it doesn't require a special transponder.

SECOR supplies only direction information; COTAR, both direction and range. Compared to DOVAP, the advantages of these systems are: 1) they supply real-time data with no films for processing; 2) they are nonambiguous systems. The jury is still out on SECOR and COTAR. One installation of each has been made and AFMTC evaluation is not yet completed.

The most accurate electronic system used by AFMTC is AZUSA. This was designed originally by Convair Div. of General Dynamics as a command technique for missile guidance. When range safety on powerful ICBM's became a serious problem, AZUSA was pressed into service as an electronic tracking system because of its high accuracy.



Firing sequencer controls countdown, monitoring of missile components and ignition. Right-hand panel contains functional relays; second panel holds countdown relays and patchboard programmer; third chassis contains automatic hold-fire panel (top), hold-fire panel (middle) and automatic sequence panel (bottom).



Fire control panel is in the hands of four different people: range safety officer (or flight safety officer), range instrumentation supervisor (or test control officer), pad safety officer (or launching officer), and contractor engineer.

And its cost is high, too. One estimate: nearly $20 million to duplicate the installation at Cape Canaveral.

Details of AZUSA's performance are classified because of its potential as a missile guidance system. It's been teamed up with an IBM 704 to form an impact predictor system. It continually calculates the trajectory of the missile and the radius on the ground in which the missile might fall if it were destroyed at any instant.

No other missile range in the U. S. can afford AZUSA. But no other facility has the range safety problem engendered by ballistic missiles. Manager of Systems Application Roy V. Godfrey explains why. "At Cape Canaveral these days," says Godfrey, "the range safety officer has practically no time to make a decision. From time of ignition to burnout —a period that can be as small as a couple of minutes —the point of impact moves from zero to maximum range of the missile. If you delay a decision a half-second, impact area will move hundreds of miles."

This points out another problem at AFMTC. The range safety officer has been getting too much information. He can't assimilate it all and make a decision in the short time available. Slowly instrument engineers have been trying to compact the data into one plotting board, removing extraneous information. Most recent development is a simplified board on which two radars, perpendicular to each other, are plotted. As long as both pens stay within previously marked paths, the flight is safe. This information with the plot from the impact predictor is almost all the human computer can assimilate in the short decision time.

Nobody at AFMTC is ready to predict what the ultimate answer will be to this problem. One guess: a special computer that will compute trajectory, compare it to a preprogrammed flight, then run the differences through a set of alternate possible actions. The final result would be to tell the range safety officer to "destruct" or "no destruct".

The reliable firing sequencer

To a control engineer, one of the most interesting devices at the AFMTC is the firing sequencer that automatically controls the countdown, the checkout, and firing of a test. RCA's John Wright, who helped design the first unit in 1951, claims the firing sequencer is the most reliable piece of equipment on the range. Every blockhouse has one. Each group of blockhouses is tied to one communications terminal building. To this building the sequencers are wired; from it go connections to the central control room, to down-range stations, and to camera and radar positions. This eliminates connecting every sequencer to every possible point on the range.

The sequencer operates for 100 min. Ninety minutes before time zero is minus time; then 10 min after *t*-zero is plus time. During that time the sequencer performs such chores as:

- Starting and stopping remote controlled cameras.
- Starting and stopping mechanisms in the missile.
- Turning on radio transmitters at Cape Canaveral, at down-range stations, and in the missile.
- Starting chart recorders in the blockhouse and at central control on Cape Canaveral.
- Programming and timing the countdown.
- Suppying the signal to ignite the missile.
- Stopping the missile launch if something doesn't operate according to schedule.

The last function is probably one of the most important. Four people located at widely separated points can stop the test through the firing sequencer: the range safety officer can order a hold if safety conditions deteriorate; the supervisor of range instrumentation can stop the countdown if he receives a report of a critical instrument breakdown; in the blockhouse, the pad safety officer can hold the test; and a representative of the missile builder can stop the test if engineers are not satisfied with the way the missile is performing.

Each of these key people has a small flat console

called a fire-control panel. At the top center, the time of the countdown is presented in digital form. Other lights indicate the status of the countdown—counting, holding, or end of sequence. If a hold is ordered, the console shows, by a warning light, who ordered the hold. Each console has a key toggle switch, covered by a red guard. That's the hold-fire switch.

There's one other way to stop the test—automatic hold fire. The sequencer can be programmed to monitor what's going on in the missile. If a circuit is supposed to operate, for example, and doesn't, the sequencer will automatically stop the countdown. If the required action then occurs, the sequencer will automatically start the countdown again. Or the machine can be programmed to require a manual reset to start the countdown.

The sequencer also has a memory to prevent certain critical operations from being interrupted. For example, suppose during fueling the supervisor of range instrumentation learns that a critical radar has stopped working. He pushes the hold-fire switch. But fueling is an operation that should be completed once it is started. So the sequencer receives the hold fire command, retains it until the fueling operation is completed, then stops the countdown until the erring radar has been repaired.

Heart of the blockhouse sequencer is the telephone-type rotary stepping switch. Actually, there are two groups of these. One is driven at one step per second by pulses from the AFMTC Timing Center. The second group moves one step at the end of each 60-sec cycle of the first group. Bank contacts of each group are connected to a patching panel, where they are identified as minutes and seconds before or after zero time.

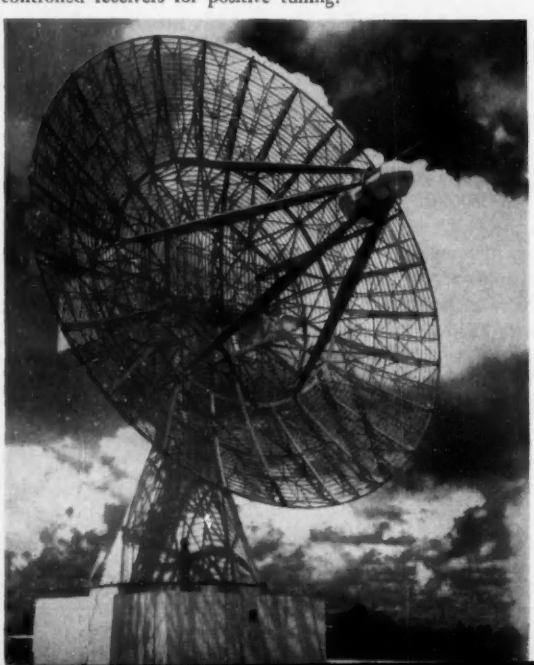
Each second is further divided into 1/5-sec intervals (new equipment now being built is divided into 1/10 sec), the smallest interval at which functions can be programmed.

Pulses appearing on the "minute" jacks are of opposite polarity to those on the "second" jacks. Connection of the coil of a self-locking relay to a "minutes" and "seconds" jack will cause the relay to be operated at a unique time in the sequence. Seventy-two such relays are provided in the sequencer; each has its own unlocking relay to terminate the event at the desired time.

With patchboard programming, says John Wright, sequences can be changed in the middle of a countdown. Usually the device is locked up. But when starting tests on a new missile, it's sometimes necessary to change the sequence of events.

A usual countdown on a big ballistic missile runs 6 to 8 hours. Some have lasted as long as 16 hours when the "bird" was balky. Because the sequencer only starts counting 90 min before time zero, AFMTC uses a countdown generator located at central control for the rest. The generator can start counting at minus 999 min; the sequencer then picks up at minus 90 min; the generator takes over again after plus 10 min.

Giant telemetry antenna with 60 ft diam dish has replaced small helical antennas. The change has helped boost gain from 10 db to 30. On the ground, stations are using crystal-controlled receivers for positive tuning.



Data reduction in the FLAC computer

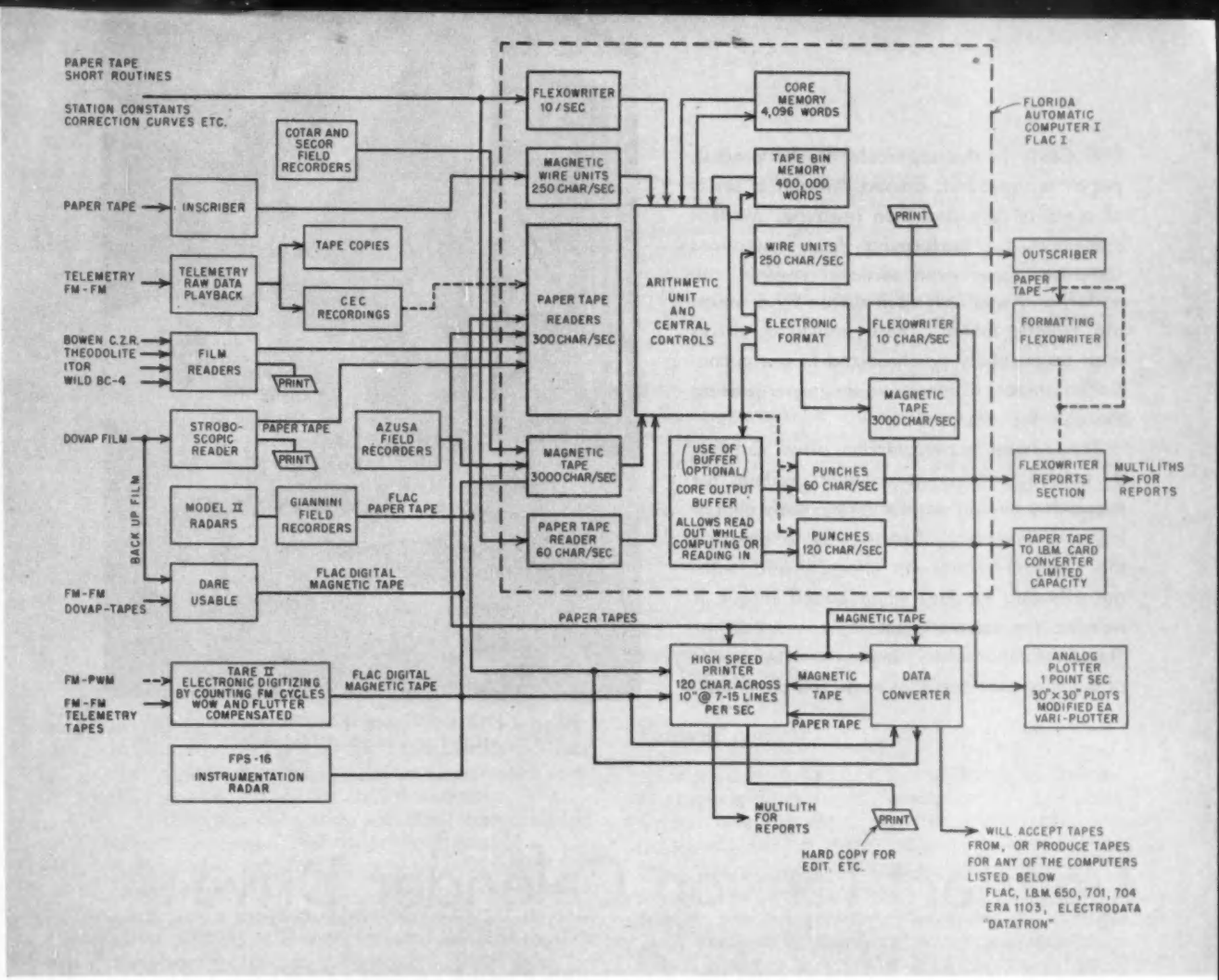
Once the missile has been fired, data is collected and starts flooding into data-reduction headquarters in the new three-story Technical Laboratory at Patrick Air Force Base. Bulk of the computation is done in FLAC, a computer modeled after National Bureau of Standards SEAC. FLAC is relatively slow in arithmetical calculations, but computation speed is not a critical requirement of AFMTC. More important is the versatility of the input and output devices. FLAC has 65 of these (see diagram, next page).

AFMTC processes no telemetry data. Its responsibility includes gathering the data at the ground telemetry stations at Cape Canaveral and down-range, and then making the number of copies a missile builder requests. The reason: since the missile builder has the calibration of the telemetry transducers, he might just as well do the computations. AFMTC has duplication equipment that can turn out up to five magnetic tape copies of a master telemetry record at one time.

The changing range

Today, at AFMTC, planning groups sense the need for a global range. A manned satellite, for example, raises five problems, not solvable by present range instrumentation. The braintwisters:

1) Where is the satellite on a real-time basis? Satellite tracking systems like the Vanguard's Minitrack tell only where the vehicle was. But if there's a man orbiting, the range must know where he is at every instant.



Data Processing at AFMTC

2) How to telemeter back to ground as many as 100 functions to help take the work load off the man in space? At satellite distances cosmic noise can be as loud as the signal.

3) How to communicate with the man? Interference with communications is common over the long distances from outer space to the ground.

4) What kind of instrumentation will be required to help bring the satellite back to earth? In an emergency, ground stations will have to have sufficient controls so that they can land the satellite like a drone.

5) How do you decide what method to use to bring the satellite back to earth? One solution would be a network of computers comparing a variety of alternate solutions, coming up with the best answer under the specific conditions.

6) How to control an outer space operation? How many control points would be necessary and where should they be?

The problems of the global range involve politics as much as technology. The number of range stations required depends on the height of the satellite. The higher it flies, the more stations are necessary. And building U.S. or United Nations range stations in countries like the U.S.S.R. or Red China might be as tough a problem to solve as the technical one of calculating time in a space vehicle.

One thing the global range seems sure to do is collapse some of the barriers between fields of science. For example, astronomers will start coming into the electrical field. Outerspace tracking will require a blending of talents. One possible meld: a specialist in guidance and control, a weatherman, and a medical man.

Nobody is yet ready to predict when the global range will be in operation. Most likely it will be the result of a steady evolution in techniques, just as the ballistic range evolved from the aerodynamic facility over the past five years.

THE GIST: In the supercalendering process, paper is unwound, passed through a series of pressure rolls and then rewound. Modern machinery for performing these operations comprises three main sections (unwind, calender, and windup), each driven by a separate electric motor. These individual drives must be carefully synchronized to put a controlled amount of tension in the paper passing through the equipment.

The newest supercalender drive employs a unique constant-horsepower system for regulating tension despite continuously changing roll diameters. The trick is to override this constant-horsepower characteristic (without affecting tension) when added torque is needed for acceleration. This override or "inertia compensation" is provided by means of memory rheostats that sense roll diameters.

FIG. 1. Windup section of supercalender installed at Champion International Paper Co.

Constant-Tension Calender Drive Features Inertia Compensation

J. V. McGAUGHY, General Electric Co.

In the present-day manufacture of paper, one process that appears ever more frequently is supercalendering, Figure 1—which imparts the desirable surface qualities of high gloss, compactness and moisture resistance. With the exception of newsprint, practically all printing paper is supercalendered. This trend has placed demands on the designers of supercalender drives and controls, notably for improved threading operation and more accurate tension control with full inertia compensation.

Supercalendering, like most converting room processes, is usually a batch type operation: it involves unwinding a previously wound roll of paper, passing it through the calender stack, and rewinding it into a new roll. It is apparent then that the operating efficiency of the supercalender is relatively low compared to the continuous operation of the main paper machinery with which it must keep pace. As papermaking and processing machine speeds increase and product quality requirements rise, it becomes more important that steps be taken to improve the operation of the supercalender so that it does not become a bottleneck in the paper production system.

A supercalender recently placed in service at the Champion International Paper Co., Lawrence, Mass., incorporates new features and components that aid in meeting the above objectives. The 126-in.-wide supercalender, which is a Rice Barton-Eck design, has a 12-roll stack and is designed for a top speed of 1,500 fpm. It is powered by a 350-hp dc motor. The unwind and windup stands are each powered by a 20/26-hp dc motor.

The main supercalender drive is of the Ward Leonard type, employing amplidyne speed regulation. The amplidyne regulator is well adapted to this type of drive since its inherent reversibility permits a rapid regenerative-braking, emergency-stop

provision that minimizes marking of the soft composition rolls following a sheet break. As seen in the basic circuit diagram, Figure 2, speed control of the main drive motor is obtained from a rheostat on the operator's desk that supplies an input signal to an electronic servo amplifier. The output of this amplifier powers a motor-operated rheostat equipped with a feedback potentiometer. With this arrangement, the main drive can be decelerated or accelerated to any preset speed without attention once the proper button has been pushed. Thus the operator is able to devote full attention to the primary task of inspecting the quality and condition of the sheet as it passes through the supercalender.

The closed-loop motor-operated speed control mechanism drives two rheostat plates to provide speed adjustment by a combination of generator voltage control and motor field weakening. Motor field weakening does not begin until the drive reaches about one-third speed. Thus essentially constant horsepower characteristics are obtained for the higher operating speeds, while additional torque is available at the lower speeds encountered when supercalendering is to be done at high nip pressures or with soft rolls. This arrangement is also helpful in providing for the very low thread speed (30 fpm) that is required of this drive since the stronger shunt field permits a higher armature voltage.

Under emergency stop operation, maximum decelerating torque is provided by means of a relay contact that immediately applies full motor field regardless of the rheostat position. An auxiliary circuit resets the motor-operated rheostat to its minimum position at a faster-than-normal rate to allow the drive to be restarted sooner. Because of the size of the main motor, the field weakening plate of the rheostat actually operates in the field of a buck exciter whose armature is in series with the supercalender drive-motor shunt field.

Threading the paper through the many nips of a supercalender represents a tedious and hazardous operation that accounts for much of the production time lost during setup. On this drive, the circuit is designed so that operation of the thread or jog pushbuttons energizes the motor-operated rheostat and moves it from minimum position to the thread-speed position, thus providing smooth acceleration of the drive to a regulated threading speed. Correct inertia compensation during this time avoids both over-tension and slack in the sheet.

The unwind and windup stands are center-driven by dc Ward Leonard drives, which produce essentially constant-horsepower characteristics. Because part of the machine speed range is covered by motor field weakening, the main supercalender generator voltage is not a true measure of drive speed. Hence a separate calender-driven generator, operated at fixed field, supplies armature voltage to the unwind braking generator and the windup motor so that they will track properly with the main drive.

Tension control

Of primary importance in the design of the unwind and windup drives is accurate control of sheet tension over the entire machine speed range, and for all roll sizes. It has become the practice to control sheet tension by regulating motor horsepower rather than directly sensing sheet tension. Such a system does not precisely compensate for changes in friction and windage losses as machine and motor speeds change. However, it is usable because most modern supercalenders, such as this one, are constructed with antifriction bearings to minimize fric-

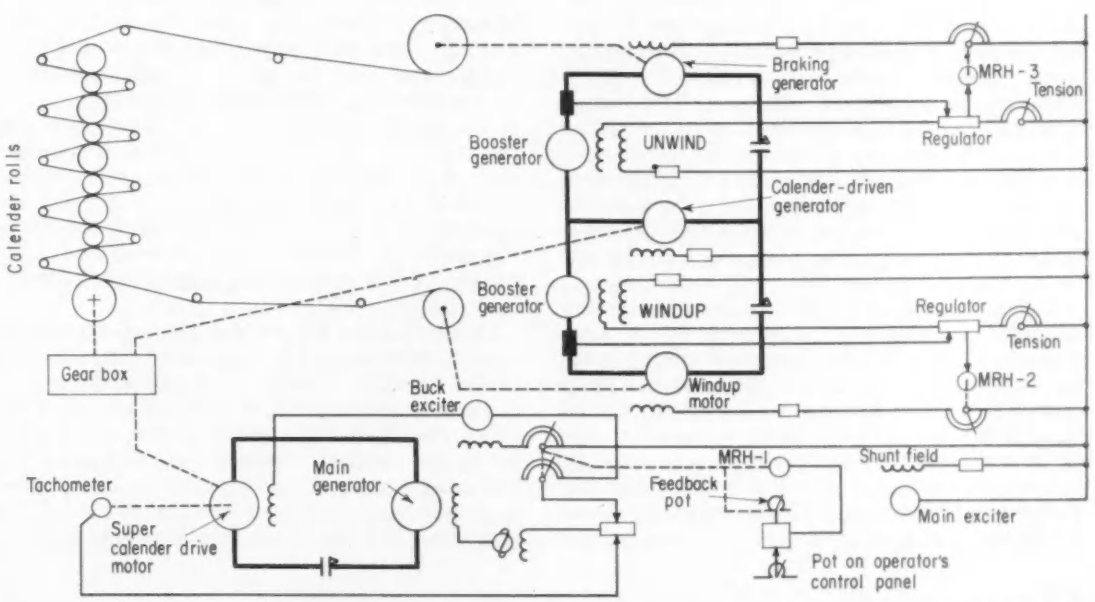


FIG. 2. Schematic diagram of three-section drive. Unwind motor is designated as braking generator since, aside from the acceleration periods, it normally operates only as a drag on the paper.

tion loads. Likewise, the unwind braking generator and windup motor are equipped with ball bearings for minimum friction and are of enclosed, separately ventilated construction to minimize changes in windage losses with changes in motor speed. The motors and generators have inherent low inertia and high momentary overload capacity.

Unquestionably, the most significant feature of this drive is in the inertia-compensation circuits. In any system using motor armature current for tension regulation, it is necessary to modify the regulation point during periods of drive acceleration and deceleration if sheet tension is to be maintained. For example, in the unwind stand it is necessary to compensate for the current required by the motor to accelerate its own armature plus the mill roll, the latter representing the larger amount of inertia. Since the amount of inertia to be accelerated or decelerated changes as the mill roll diameter changes, it follows that the correct amount of current compensation also changes.

In the past, inertia compensation circuits were generally arranged to provide a fixed correction, with the nominal value of compensation set for 70 percent maximum roll diameter (that value representing 50 percent of the total amount of paper and 50 percent change in weight). Thus the drive would be undercompensated for mill rolls having more than 70 percent of the maximum diameter remaining and over-compensated for rolls smaller than this size. For this equipment, an inertia compensation circuit was devised in which the amount of compensation changes as the roll diameter changes, so that the correct value of compensation is available for speed changes of all sizes of rolls. Therefore, sheet tension remains essentially constant.

The basic circuits for the unwind braking generator and the windup motor are shown in the right-hand portion of Figure 2. Both circuits are substantially equivalent, so that the operation of only the unwind section will be described. A measuring resistor is placed in the loop to develop a voltage that is proportional to the dc current. This voltage signal is compared to an adjustable reference voltage and the difference becomes the input to a two-stage magnetic-amplifier regulator whose output controls the field of a booster generator. Since the armature of the booster generator is in series with the armature of the unwind braking generator, the loop current is regulated by controlling the booster voltage.

The unwind stand is center-driven; hence, the roll speed must rise as the paper roll builds down in order to maintain a constant sheet speed. Simultaneously, the counter emf of the unwind braking generator increases with its speed, assuming a fixed shunt field. Such a change in the counter emf normally would cause an increase in loop current. In this case, however, it is sensed by the magnetic amplifier current regulator, which functions to reduce the booster voltage sufficiently to return the current to its original value. This preserves the constant-horsepower conditions needed to assure unchanging tension in the web.

As the paper roll in the unwind stand builds down from maximum diameter to core size, the counter emf change in the unwind braking generator will exceed the available voltage range of the booster generator. Therefore, an additional refinement is incorporated in the circuit to compensate further for changes in counter emf. The armature of a motor-operated rheostat is placed across the output of the magnetic preamplifier and in series with an adjustable bias voltage and a blocking rectifier. As the regulator functions to maintain constant loop current during roll build-down, the output of the magnetic preamplifier increases. When this output voltage exceeds the bias voltage, current flows through the blocking rectifier and through the armature of the motor-operated rheostat, causing it to rotate. One plate of this rheostat is placed in the shunt field of the unwind braking generator, and as the rheostat moves it recalibrates the shunt field to maintain the counter emf at nearly a fixed value despite speed changes. Hence, the booster remains in mid-range while regulating loop current.

Since the motor-operated rheostat moves as a function of roll diameter, it can be used to advantage in providing the varying inertia compensation previously mentioned. A second plate is added to the rheostat and connected in the inertia compensation circuit in such a way as to modify the compensation signal with roll diameter changes. If the drive is stopped with a roll in the unwind stand, the rheostat will remain set at the correct position to provide proper inertia compensation when the drive is restarted. For this reason this compensating circuit is often referred to as a "memory rheostat system". Another circuit resets the rheostat to the "full roll" position when the mill roll core is replaced with a new roll. This may be done automatically, by a limit switch mounted on the stand and actuated when the roll is changed, or manually by a pushbutton on the operator's desk.

The problem of inertia compensation arises also in the windup section and is handled in the same manner through the use of another motor-operated rheostat. The circuit essentially duplicates the unwind circuit, except that the motor field and inertia compensation functions are reversed, since the windup section starts with an empty core and builds up to full roll size.

Figure 3 shows the unwind tension regulator in block diagram form. The function of the main loop labeled "current feedback" is to adjust the output of the booster generator so as to maintain the current in the unwind generator (I_a) at the level called for by the "tension-reference" potentiometer. The bottom loop controls the output of the buck exciter (not shown in Figure 2) in the field of the braking generator. The inertia compensation loop is active

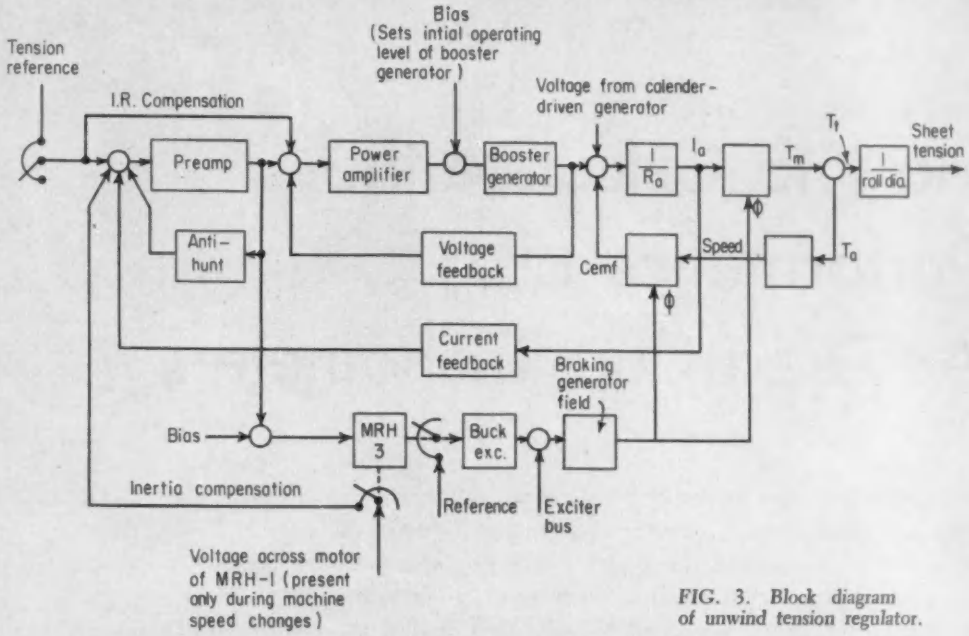


FIG. 3. Block diagram of unwind tension regulator.

only during machine speed changes. During acceleration, for example, this loop serves to increase I_a over the amount called for by the tension reference. The amount of this increase depends on the diameter of the unwind roll as indicated by the position of the memory rheostat. The five boxes at the right of the diagram establish the relationships among the various operating characteristics of the drive. For example, motor torque T_m is the product of armature current I_a and field flux ϕ. Note also that total motor torque is divided into accelerating torque T_a and the torque T_t for tensing the sheet.

In winding some types of paper, it may be desirable to taper the tension, that is, to change the sheet tension between the supercalender and the windup stand as the wound-roll diameter increases. This is done to maintain a smooth uniform edge and to prevent telescoping of the roll. This function is usually performed manually by the operator who will readjust the tension rheostat to give the taper desired for a particular job. It is interesting to note that this function is easily made automatic with the memory rheostat system by adding a third plate to the motor-driven rheostat in the windup motor circuit to gradually change tension as the roll builds up. Besides providing a smooth and accurate taper, this system frees the operator for other tasks. However, it is somewhat inflexible, since a given rheostat plate can provide only one taper configuration; additional circuit components must be used to modify the original value of taper. The problem then is one of recognizing what value of taper is best.

For emergency stop, the unwind and windup motors employ dynamic braking. Regenerative braking of these sections is not feasible for emergency stop since the energy returned to the calender-driven generator would appear as additional energy to be dissipated in the main calender drive. This would lengthen the stopping time of the supercalender stack. Stopping either the unwind or windup with the main drive still running will initiate a dynamic braking stop for that section.

The operator controls have been laid out to provide the functions necessary for all normal modes of operation and at the same time to keep the complexity and number of controls to a minimum. The controls provided for the main supercalender section are: jog, thread, run, stop, emergency stop, and master speed rheostat. For the unwind section, the controls are: payout, unwind tension on, tension adjust, unwind off, and unwind reset. For the windup, the functions are: thread, windup tension on, tension adjust, windup off, and windup reset.

There is no payout speed rheostat, since the payout speed of the unwind remains essentially constant regardless of roll diameter. Therefore, it is necessary only to provide an adjustable resistor in the control panel to initially adjust the payout speed. Operation of the payout button sets up the unwind circuit so that operation of the calender jog or thread pushbutton will allow the unwind to pay out sheet at the preset speed (a speed normally set slower than the calender thread speed to maintain a tight sheet). Operation of the tension-on button for the unwind section will cause the tension regulator to maintain sheet tension set on the unwind tension adjust rheostat while the calender is operating at thread or running speed. If the unwind is left on payout and the button is operated, it will automatically transfer to tension control.

How to Calculate the Performance of Ac Drag Cup Tachometers

THE GIST: The basic theory of the ac drag cup tachometer generator has been described in some detail in three valuable papers (Refs. 1, 2, 3). But none of these has yielded a straightforward way of calculating the tachometer's performance characteristics from given design constants. This article develops a simple expression which, with some typical parametric graphs, permits calculation of the output voltage gradient (volts per thousand rpm) and its nonlinearity over a stated speed range for any ac drag cup tachometer of known parameters. The curves included are for the usual feedback system requirement of zero phase angle between tachometer input and output, but others can be calculated easily.

TAI NIEN FENG
John Oster Mfg. Co.

NOMENCLATURE

a	Effective turns ratio of output winding to input winding
L	Nonlinearity, percent
r_1	R_1/X_m
r_2	R_2/X_m
R_1	Input winding resistance
R_2	Drag cup resistance
S	Per unit synchronous speed
v_{in}	Input voltage
v_o	Open-circuit output voltage
x_1	X_1/X_m
X_1	Primary leakage reactance
X_m	Magnetizing resistance

Certain simplifying assumptions can be made validly which yield useful expressions for the output gradient and linearity of ac drag cup tachometer generators. These assumptions are:

- all space and time harmonics are negligible
- secondary leakage reactance X_2 is negligible compared to the magnetizing reactance X_m
- core losses are negligible
- the output winding impedance is much smaller than the load impedance, hence the tachometer may be considered open-circuited

The basic output voltage equation can be derived from either the revolving-field theory (Ref. 2) or the cross-field theory (Ref. 3), and with the above assumptions becomes:

$$\frac{v_o}{Sav_{in}} = \frac{1}{A + jB + (C - jD)\,S^2} \tag{1}$$

where A, B, C, and D are constants that depend on design relationships (see nomenclature):

$$A = r_2\,(1 + x_1) + 2\,r_1 - (x_1/r_2) \tag{2}$$

$$B = 1 + 2x_1 + (r_1/r_2) - r_1\,r_2 \tag{3}$$

$$C = x_1/r_2 \tag{4}$$

$$\text{and } D = r_1/r_2 \tag{5}$$

A and B determine the gradient and phase angle of the output voltage and C and D determine the deviation in the gradient and phase angle at various

operating speeds. In other words, A and B predominate the gradient and phase angle, while C and D only affect the magnitude of in-phase and quadrature components of nonlinearity at high operating speeds. Therefore, an analysis of the performance of an ac drag cup tachometer generator may separate considerations of gradient, phase angle, and nonlinearity.

Gradient and phase angle

When the tachometer generator is operated much slower than its synchronous speed, the third term of the denominator in Equation 1 may be assumed zero. Thus the equation reduces to:

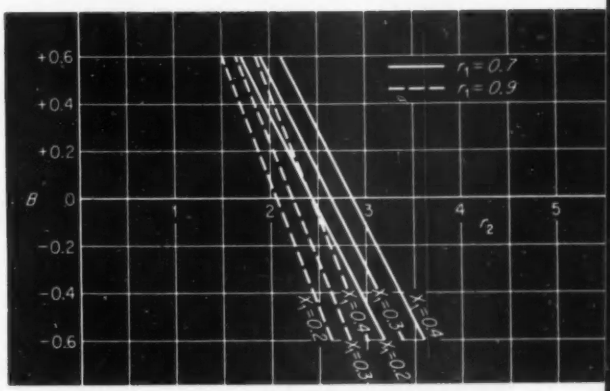
$$\frac{v_o}{Sav_{in}} = \frac{1}{A + jB} \tag{6}$$

$$\text{or } v_o = Sav_{in}\, Y \angle -\phi \tag{7}$$

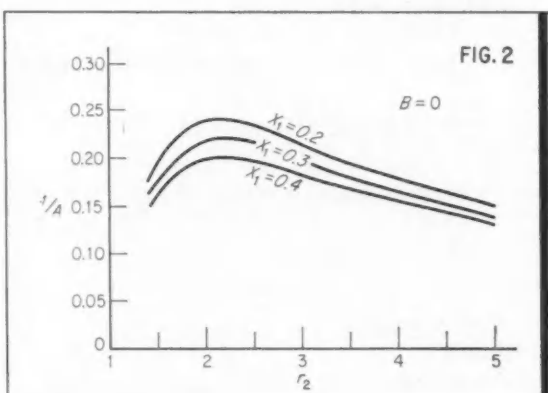
$$\text{in which } Y = 1/\sqrt{A^2 + B^2} \tag{8}$$

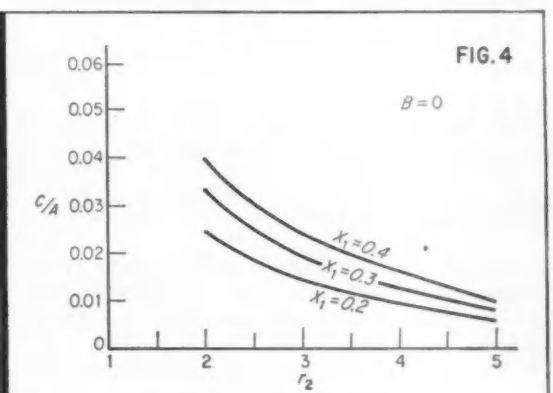
$$\text{and } \phi = \tan^{-1}(B/A) \tag{9}$$

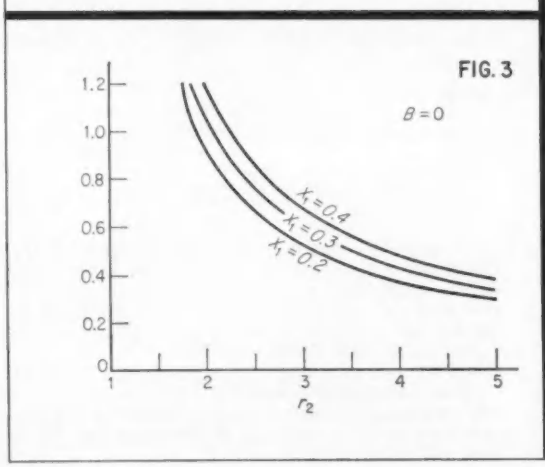
FIG. 1. Relationship of imaginary component of output voltage gradient to drag cup resistance.

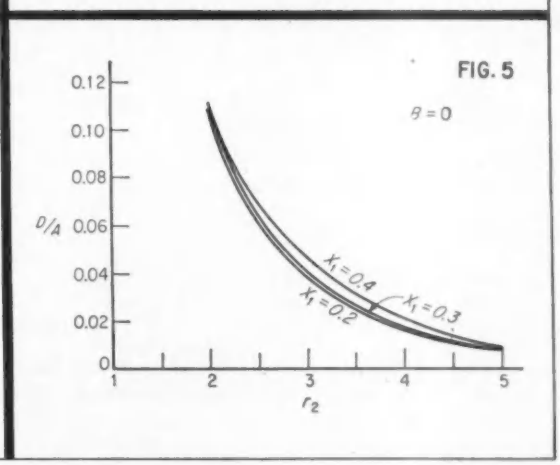


PARAMETRIC RELATIONS IN AC DRAG CUP TACHOMETERS DESIGNED FOR ZERO PHASE SHIFT









In a feedback system, the output voltage of a tachometer generator is normally required to be in phase with the reference or input voltage. In this case, B must equal zero, and Equation 7 becomes:

$$v_o = \frac{Sav_{in}}{A} \angle 0 \qquad (10)$$

Nonlinearity

By definition, nonlinearity is the deviation of the output gradient as a function of speed. It may be therefore expressed as follows:

$$L = \frac{\text{gradient at given speed} - \text{gradient at zero speed}}{\text{gradient at zero speed}}$$

That is:

$$L = \frac{\dfrac{1}{A + CS^2 + j(B - DS^2)} - \dfrac{1}{A + jB}}{\dfrac{1}{A + jB}} \qquad (11)$$

$$L = \frac{1}{1 + \dfrac{(C - jD)S^2}{A + jB}} - 1$$

$$\text{or, } L \leqq \frac{(C - jD)}{A + jB} S^2$$

$$L = \frac{-(AC - BD) + j(AD + BC)}{A^2 + B^2} S^2 \qquad (12)$$

And if $B = 0$, Equation 12 becomes:

$$L \leqq \frac{-C + jD}{A} S^2 \times 100 \text{ (percent)} \qquad (13)$$

Performance analysis

Some of the considerations in the design of ac tachometer generators are useful in understanding their performance. In brief, these design considerations are:

- The starting point of design is the phase angle between output and input voltage. For a zero phase angle, the parameters must be so designed that Equation 3 is equal to zero.
- The optimum design for maximum gradient with given phase angle can be determined analytically. For example, with the requirement of zero phase angle

$$B = 1 + 2x_1 + (r_1/r_2) - r_1 r_2 = 0 \qquad (14)$$

Solving this equation for r_1,

$$r_1 = \frac{r_2(1 + 2x_1)}{r_2^2 - 1}$$

and substituting into Equation 2 yields:

$$A = r_2(1 + x_1) + \frac{2r_2(1 + 2x_1)}{r_2^2 - 1} - \frac{x_1}{r_2} \qquad (15)$$

The maximum value of Equation 15 can be found by setting its differential equal to zero, i.e.:

$$(1 + x_1) r_2^6 - (4 + 5x_1) r_2^4 - (1 + 5x_1) r_2^2 + x_1 = 0 \qquad (16)$$

Solving Equation 16,

$$r_2 \leqq \sqrt{\frac{4.25 + 6x_1}{1 + x_1}} \qquad (17)$$

and, for very small values of x_1 ($x_1 << 1$),

$$r_2 \leqq 2.06 \qquad (18)$$

Figure 2 shows that, given the requirement of zero phase angle and the limited range of x_1, the drag cup resistance should be approximately two to two and a half times the magnetizing reactance.

(These derivations are for the requirement of zero phase angle only—other conditions can be derived accordingly.)

- The nonlinearity is closely related to the leakage reactance and primary resistance; for this reason good linearity depends on keeping the leakage reactance and primary resistance as small as possible.

Figures 1 through 5 will simplify calculations of the performance of ac drag cup tachometer generators within the range of parameters normally encountered in feedback control systems. To see how these curves are used, consider a tachometer generator with the following constants:

$v_{in} = 115$ volts $a = 0.29$
$r_1 = 0.80$ $x_1 = 0.30$
synchronous speed = 12,000 rpm
$r_2 = 2.41$

From Figure 1, it may be interpolated that:

$$B = 0$$

With $B = 0$, from Figure 2,

$$1/A = 0.217$$

from Figure 4,

$$C/A = 0.027$$

and from Figure 5,

$$D/A = 0.072$$

Then calculate:

$$\text{gradient} = \frac{115 \times 0.29 \times 0.217 \times 1{,}000}{12{,}000} = 0.604 \text{ volts/1,000 rpm}$$

the phase angle: $\phi = 0$ deg

If the maximum operating speed of this tachometer generator is 4,800 rpm, or $S \leqq 0.4$, then from Equation 13,

$$L \leqq (-0.43 + j\,1.15) \text{ percent}$$

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Flexible Selection of Thermistors

DOV MALKIN
American Electronics, Inc.

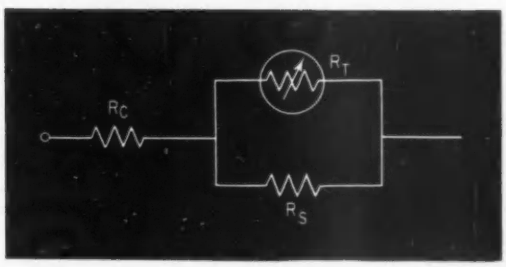

FIG. 1. Thermistor-compensated network.

Several thermistor manufacturers furnish charts (Ref. 3) for the design of thermistor-compensated networks. Each chart, however, gives a single rigid solution, correct for only that manufacturer's product. The method described here enables the designer to evaluate stock thermistors produced by many manufacturers and having a wide variety of tolerances, and to choose the appropriate one with a knowledge of the consequences.

Figure 1 shows the compensating network. In the figure:

R_C = resistance, at t deg C, of the copper element to be compensated
R_{CO} = resistance of this element at t_o deg C ambient (usually taken as 25 deg C)
R_T = thermistor resistance at t deg C
R_{TO} = thermistor resistance at t_o deg C ambient (usually taken as 25 deg C)
R_S = shunt resistance (nonvariant with temperature)
R_{TOTAL} = total resistance of network

For copper (only the constant is different for other materials),

$$R_C = \left(\frac{234.5 + t}{234.5 + t_o}\right) R_{CO} \qquad (1)$$

$$R_{TOTAL} = R_C + \frac{R_T R_S}{R_T + R_S} \qquad (2)$$

Dividing Equation 2 by R_{TO},

$$R_{TOTAL} = R_{TO}\left[R_C/R_{TO} + \frac{R_T/R_{TO} \cdot R_S/R_{TO}}{R_T/R_{TO} + R_S/R_{TO}}\right]$$

$$= R_{TO}\,[R_C/R_{TO} + r_Z] \qquad (3)$$

where $r_Z = \dfrac{R_T/R_{TO} \cdot R_S/R_{TO}}{R_T/R_{TO} + R_S/R_{TO}}$

Equation 3 shows that for R_{TOTAL} to be constant over the temperature range of an application (this is the objective of temperature compensation), $(R_C/R_{TO} + r_Z)$ must be constant. Substitution of Equation 1 into Equation 3 reveals that this will be so if

$$\left[\left(\frac{234.5 + t}{234.5 + t_o}\right) R_{CO}/R_{TO} + r_Z\right] \text{ is constant.} \qquad (4)$$

Letting $\dfrac{R_{CO}/R_{TO}}{234.5 + t_o} = K$ and differentiating Equation 4 with respect to temperature t,

$$K = -\frac{\Delta r_Z}{\Delta t}$$

Therefore, since $t_o = 25$ deg C,

$$R_{TO} \cong \frac{R_{CO}}{260\,K} \text{ when } R_{TOTAL} \text{ is constant.}$$

$K = \Delta r_Z/\Delta t$ is scaled from Figure 2, a plot of r_Z vs. temperature prepared by assuming values of R_S/R_{TO} and averaging values of R_T/R_{TO} scaled from plots of R_T/R_{T_o} vs. temperature. These plots were furnished by

- General Electric, for its Grade 2 thermistors
- Gulton Industries, for its Grade R thermistors
- Veco Thermistor, for its Grade B thermistors
- Keystone Thermistor, for its Series 70 thermistors

The table (next page) summarizes data for compensation between −25 deg and +75 deg taken from Figure 2 and generalized by making $R_{CO} = 1$. The fourth column lists solutions of Equation 5 for

1 R_S/R_{TO}	2 D_{max}, Max deviation of r_Σ from linearity	3 $\Delta r_\Sigma/\Delta t$	4 R_{TO}, Eq. 5, ohms	5 R_{TOTAL}, Eq. 6, ohms	6 Deviation of solution from perfect compensation, Eq. 7, percent
1	±0.04	0.0081	0.474	1.237	±1.54
0.9	0.035	0.0073	0.526	1.249	1.44
0.8	0.025	0.0066	0.585	1.261	1.19
0.7	0.025	0.0055	0.704	1.289	1.4
0.6	0.025	0.0046	0.826	1.31	1.6
0.5	0.025	0.0037	1.045	1.347	1.93
0.4	0.02	0.0028	1.39	1.397	2.01
0.3	0.0175	0.0019	2.01	1.463	2.39
0.2	0.015	0.0011	3.52	1.586	3.34
0.1	0.0075	0.00043	8.92	1.8	3.72

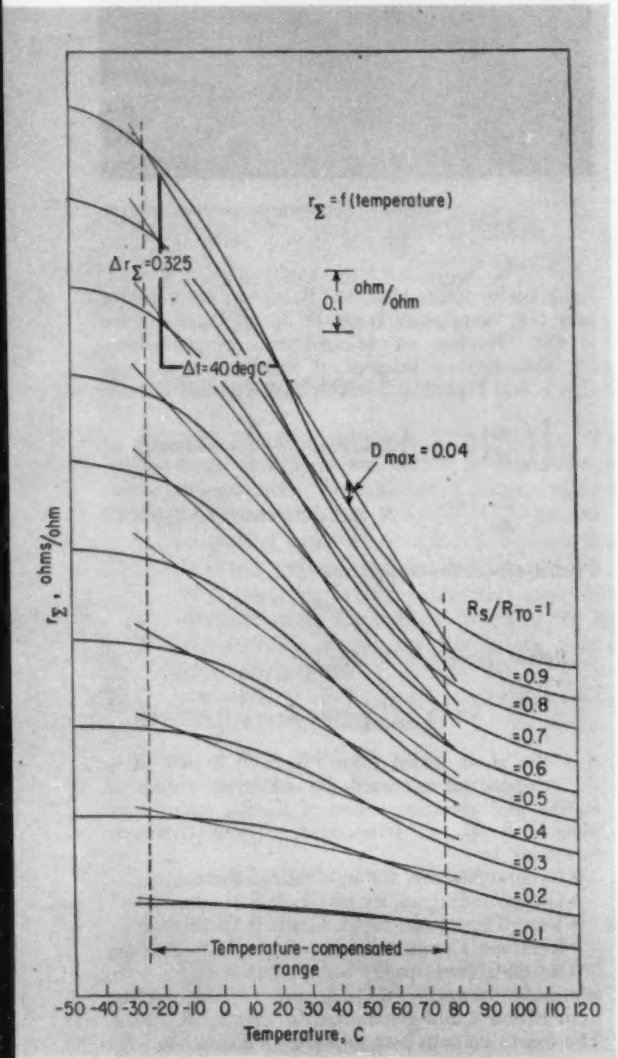

FIG. 2. Curves of nondimensional relationship between resistances in thermistor-compensated network lead to a simple method for selecting commercially available standard thermistors.

values of R_s/R_{TO} ranging from 0.1 to 1. R_{TOTAL} (fifth column) is determined from Equation 2 at t_o deg C and rewritten to use directly the data gathered from Figure 2:

$$R_{TOTAL} = R_{CO} + \frac{R_{TO} \cdot R_S/R_{TO}}{1 + R_S/R_{TO}} \qquad (6)$$

Percent deviation from perfect temperature compensation over temperature limits from −25 deg C to +75 deg C is calculated from

$$100 \frac{D_{max} \cdot R_{TO}}{R_{TOTAL}} \qquad (7)$$

and tabulated in the final column. D_{max} is the maximum deviation scaled from the curve in Figure 2.

The curves in Figure 2 and the table are correct for the thermistors listed. For other thermistors (for which the author has not verified Figure 2), it may be necessary to draw a new set of curves.

An example demonstrates use of the table for the thermistors listed.

R_{co} = 100 ohms

The last column of the table indicates that for minimum deviation a thermistor with resistance R_{TO} = 58.5 ohms should be used; 50-ohm and 75-ohm thermistors, however, are standard. Choosing the 75-ohm thermistor because of better price and size, R_{TOTAL}, from column 5, equals 129.5 ohms (by interpolation) and the solution deviates by plus or minus 1.45 percent from perfect compensation. Solved for with Equation 2, R_s = 48.6 ohms, but again 50 ohms is a standard value. Using it and running back through the solution, the deviation increases only to plus or minus 1.50 percent.

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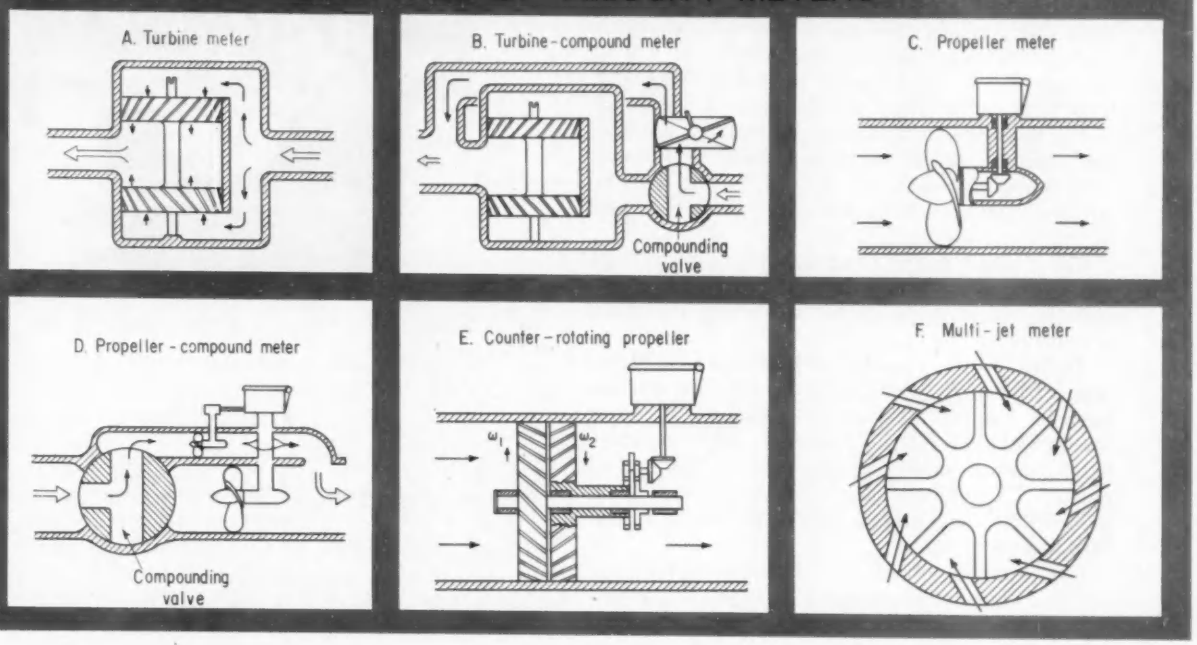
3. *A THERMISTOR SELECTING SHORTCUT*, "Control Engineering", Jan. 1957, p. 73

Table 1 SIX TYPES OF VELOCITY METERS



WHAT YOU SHOULD KNOW ABOUT

Velocity Flowmeters

RUSSELL W. HENKE, Russ Henke Associates

In a previous article* the author reviewed the characteristics and applications of positive displacement meters. On the following pages he covers another, perhaps less familiar, class of volumetric flowmeters: velocity meters. Application of these meters has been hampered more by lack of information about their characteristics than anything else. This article should help alter this situation by acquainting the reader with the various types.

* *See CONTROL ENGINEERING, May 1955, "What You Should Know About Positive Displacement Meters", pp. 56-64.*

Velocity meters are flow-sensitive instruments that convert velocity of a flowing liquid to a sensible mechanical output in the form of spindle rotation. This output can be coupled to devices which will

a. integrate and register the total quantity of fluid that has passed through the meter, or
b. control some other piece of equipment or process.

In general, the velocity- or "inferential"-type flowmeter may be said to take up where the positive displacement meter leaves off. Both offer a fairly linear response to variations in flow and both provide a very useful mechanical output. The principal difference is in maximum flow rate: for a given size and pressure drop, the velocity-type meters will accommodate a considerably higher rate.

Table I illustrates six basic types of velocity flowmeters. Their descriptions follow.

TURBINE METERS

In Figure 1, liquid enters the turbine rotor from both ends, passes through the wheels, and exits through the space between the wheels. In flowing through the turbine wheels, it strikes the blades. This "reaction impulse" on the blade is a function of the mass of liquid flowing and the magnitude of the velocity change. As this reaction force increases, rotor speed increases. At any given flow rate an equilibrium point will be reached at which the speed of rotation is constant.

Rotor speed under these conditions then is an analog of the liquid flow rate. It can be fed to any suitable secondary device for indicating, recording, or controlling.

Turbine meters operate most efficiently at higher rates of flow. As flow rate drops off, the reaction force on the turbine loses its ability to overcome mechanical loads. Finally, the meter stops operating. Error increases rapidly as this point is approached (Figure 2A). Figure 2B shows the corresponding pressure-loss curve. Both curves are for a typical 6-in. turbine meter.

The principal job of turbine meters is metering liquids over a wide range of relatively high flow rates. Their usual instrumentation reads out *total volume* or quantity of liquid passed, but they can also be equipped to indicate instantaneous *rate* of flow. Typically, they control a variety of water treating processes, using mechanical or electrical programmers in the treatment cycle, and blending and mixing processes where predetermined quantities of different liquids must be added. In these latter applications, auxiliary instrumentation to control the size of the batch is mounted on the meter and driven by the meter spindle.

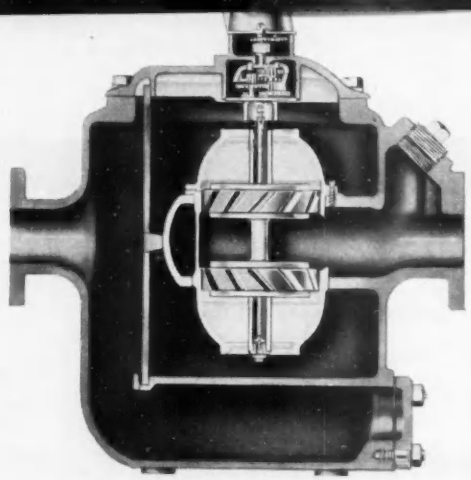


Fig. 1. Simple turbine flowmeter. Badger Meter Mfg. Co.

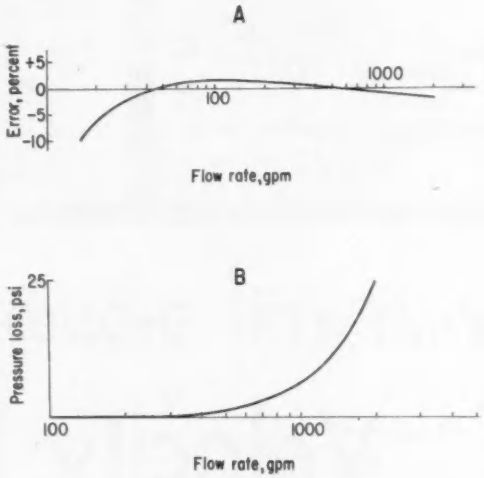


FIG. 2. Reading error (A), and pressure drop (B) through a simple turbine meter plotted against flow rate. Latter scale is logarithmic.

TURBINE-COMPOUND METERS

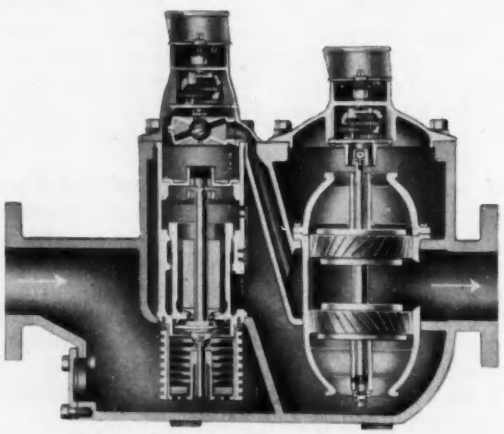


FIG. 3. Turbine-compound flowmeter. Badger Meter Mfg. Co.

The relatively high error of the turbine meter in the low-flow range prompted development of the turbine-compound meter (Figure 3). This meter combines the low-flow sensitivity of positive displacement with the high capacity of a turbine design. A compounding valve between the p-d and the turbine stages diverts flow from one stage to the other, depending on the flow rate.

Figure 4 illustrates the action. At A, the valve is in its normal low-flow position; here all the liquid flows through the positive-displacement stage. As flow rate increases, it lifts the center section until, at B, it reaches a "crossover" value and the positive displacement stage is sealed off. Full pressure is then brought to bear on the entire bottom face of the compounding valve, causing the heavy cylin-

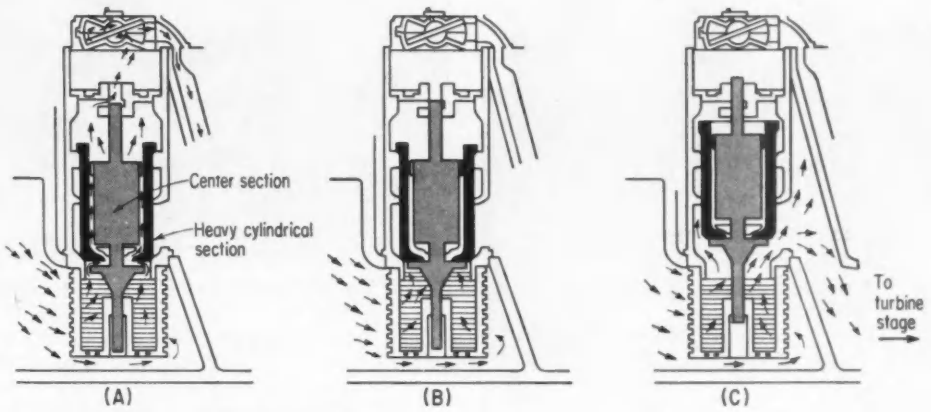


FIG. 4. Operation of the compounding valve for the meter of Figure 3.

drical section to rise and open the porting to the turbine stage, C.

At low flow rates, the t-c performs with the accuracy of the positive displacement stage; at high flow rates, with that of the turbine stage. But at crossover, because of the disturbing influence of shifting, accuracy drops below that of either stage. A typical error-flow curve and its corresponding pressure-loss curve are shown in Figures 5A and 5B. Loss of accuracy at crossover must be taken into consideration when applying this meter in control.

In general, the turbine-compound meter and the simple turbine meter have the same area of application. The former, however, is applicable over a much wider flow rate range—and at considerably lower flow rates. Auxiliary instrumentation is also very similar.

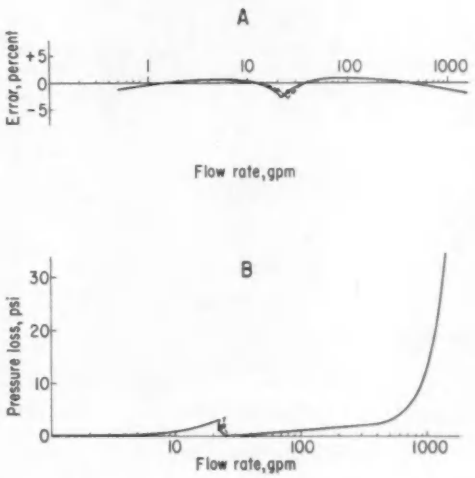


FIG. 5. Reading error (A), and pressure drop (B) through turbine-compound meter plotted against flow rate. Note hysteresis effect at "crossover".

PROPELLER METERS

A propeller-type sensing element in the meter in Figure 6 converts the liquid's velocity reaction into driving torque. Its purpose is essentially the same as the turbine meter, i.e., to provide greater metering capacity than the positive displacement design. In certain special applications, it is even more suitable than the turbine type. The propeller counterpart of the turbine-compound meter (Figure 7) consists of one large and one small propeller meter. To overcome low-flow disadvantages, the primary unit can be compounded with a positive-displacement meter, as in the turbine-compound type.

One propeller meter, Figure 8, is well suited to metering gaseous or vapor-phase media. It combines an orifice plate in the main stream and a by-pass section for the propeller element. A portion of the fluid is by-passed through this propeller element and the secondary instrumentation is calibrated to read total flow.

The duo-rotor meter, a late development, uses two counter-rotating propellers to extract maximum energy from the liquid. This improves accuracy at low flow rates and over the entire flow range.

Figure 9 shows an interesting adaptation of the propeller design. This one measures liquid entering or leaving a reservoir by means of a conductor in its side; it might also be used for measuring flow in an open channel. Still another variation (Figure 10) uses the vertical flow principle to measure irrigation water.

Propeller meters are used in pipe lines, water mains, and high-flow applications that require a low permanent pressure drop combined with a mechanical output.

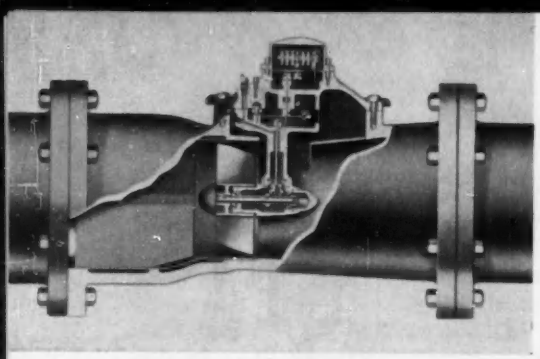


FIG. 6. Sectional view of a simple propeller meter. Builders-Providence, Inc.

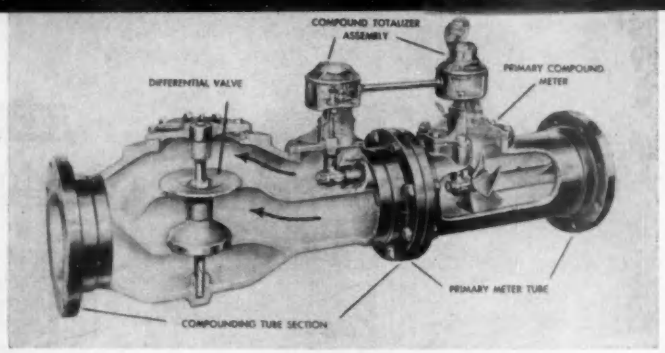


FIG. 7. Typical propeller-compound meter. Sparling Meter Co.

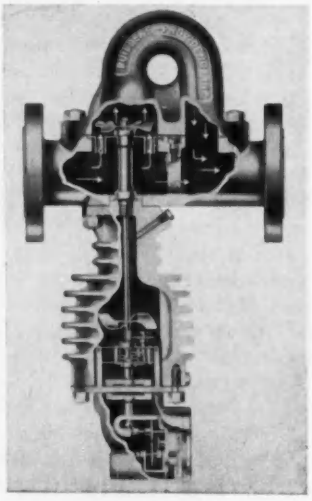


FIG. 8. Combined orifice and propeller meter for gaseous fluids. Builders-Providence, Inc.

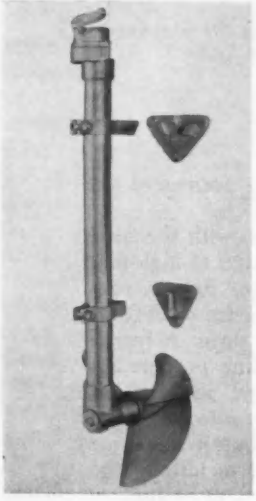


FIG. 9. Propeller-type meter suited to measuring flow in an open channel. Sparling Meter Co.

FIG. 10. Vertical-flow propeller meter for irrigation metering. Sparling Meter Co.

MULTI-JET METERS

In another general type of velocity meter, the multi-jet meter (type F, Table I), a paddle-wheel-type rotor responds to a series of radially displaced jets. Widest use is in water-works and other areas involving liquids with suspended solids (such as light slurries). High accuracy is not a characteristic.

The vane meter in Figure 11 is a variation of the multi-jet type. Location of the nozzles with respect to the chamber periphery is such that a vortex action is set up by the flow. The vanes rotate within this vortex, offering very little resistance to flow. Because of unobstructed passages and a generous clearance around the vanes, suspended solids pass through the meter without impairing operation.

This meter registers within 2 percent of absolute accuracy over the flow range from 20 to 100 percent of rated capacity.

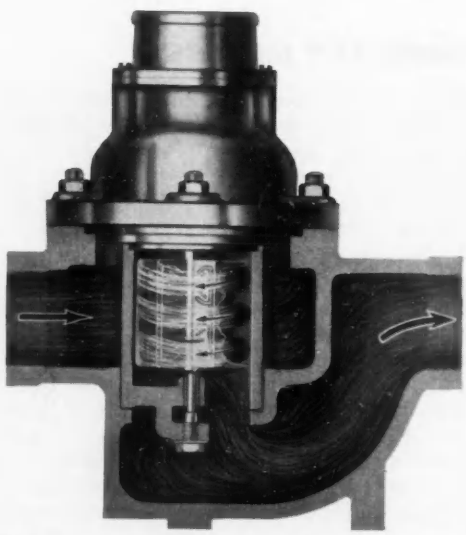


FIG. 11. A variation of the multi-jet type; this meter readily handles suspended solids. Henszey Co.

VORTEX-VELOCITY METERS

A newcomer to the line of velocity meters is the vortex-velocity meter in Figure 12. This meter passes a large volume of liquid for its size (a 220-gpm model fits "in-line" in a 2-in. pipe and measures only 12 in. in overall length). Its sensitivity is extremely good.

When a pressure differential causes a flow through the meter, the static fluid in the case will shear (Figure 13A) because of viscous friction between the static and dynamic fluids. This action forms a true vortex, which constricts the flow, as shown in Figure 13B. After the operating flow pattern is set up, the cage simply counts revolutions of the vortex pool. Pressure drop is low (about 3 psi maximum at full rated capacity of the 220-gpm model). This compares very favorably with other types of velocity meters.

The vortex-velocity meter can be adjusted for changes in density and viscosity, and has the following instrumentation: a mechanical totalizer to record total quantity of liquid passed, a rate-of-flow indicator, and an electric ticket printer to record quantity delivered. It shows promise for applications involving a restriction in the fluid line, suspended solids in the fluid, or critical meter size. The metering principle it represents will bear watching.

FIG. 12. Vortex-velocity meter combines small size with a large capacity and good sensitivity. Rotron Controls Corp.

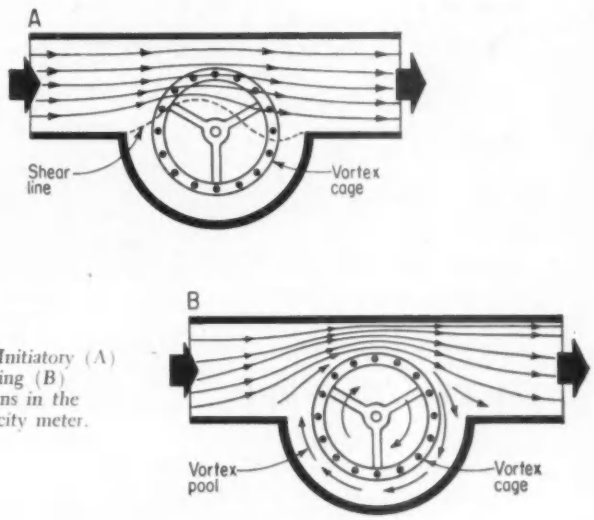


FIG. 13. Initiatory (A) and operating (B) flow patterns in the vortex-velocity meter.

VELOCITY VS. P-D METERS

It has been said that positive-displacement and velocity-type meters perform the same general functions, one at the lower and one at the higher flow rates. Table II compares the maximum flow rates of one positive-displacement meter and a variety of velocity meters. Note the overlap of sizes. Table III shows the maximum pressure losses for five of the types in Table II.

Take the 2-in. positive-displacement meter as the standard of comparison. The 2-in. turbine type has about 156 percent capacity and 450 percent pressure loss; the 2-in. t-c meter also has 156 percent capacity, and in addition has a 750 percent pressure loss; the 2-in. propeller meter has 56 percent capacity but only 22 percent pressure loss; and the 2-in. vortex-velocity meter (not listed) has 137 percent capacity and an estimated 75 percent pressure loss.

Now compare the 6-in. meters. The turbine meter has 190 percent capacity and an estimated 150 percent pressure loss; the t-c meter exhibits 143 percent capacity and an estimated 150 percent head loss; the propeller meter shows a 95 percent capacity and a 2.5 percent pressure loss; and the propeller-compound meter also has 95 percent capacity with a 20 percent head loss.

The following generalizations can be made:

- Turbine and t-c meters have greater capacity than displacement meters of the same nominal size.
- Propeller and propeller-compound meters have slightly smaller capacities than displacement meters of the same size.
- Turbine and t-c meters have the greatest permanent pressure loss, propeller-type meters the least.
- Positive displacement meters have the highest

TABLE II—COMPARATIVE METER CAPACITIES

Positive Displacement (Nutating Disc)

Meter size, in.	⅝	¾	1	1¼	1½	2	3	4	6
Capacity, gpm	26	40	65	82	130	160	350	550	1050

Turbine

Meter size, in.	2	3	4	6	8	10	12
Capacity, gpm	250	500	900	2000	3500	5500	8000

Turbine-Compound

Meter size, in.	2	3	4	6	8	10	....
Capacity, gpm	250	500	650	1500	2760	3200	....

Propeller

Meter size, in.	2	3	4	6	8	10	12
Capacity, gpm	90	215	400	900	1300	1800	2400

Propeller-Compound

Meter size, in.	...	...	...	6/2	8/3	10/3	12/4
Capacity, gpm	...	...	...	900	1200	1600	2250

Vane-Velocity

Meter size, in.	¾	1	2	3	4	....	....
Capacity, gpm	10	30	150	300	600	....	....

TABLE III—COMPARATIVE PRESSURE LOSSES

Positive Displacement (Nutating Disc)

Meter size, in.	⅝	¾	1	1¼	1½	2	3	4	6
Pressure loss, psi	15	8.5	14	25	9	4	10	9	...

Turbine

Meter size, in.	2	3	4	6	8	10	12
Pressure loss, psi	18	16	30	28	23	19	30

Turbine-Compound

Meter size, in.	2	3	4	6	8	10	....
Pressure loss, psi	30	25	26	30	28	25	....

Propeller

Meter size, in.	2	3	4	6	8	10	12
Pressure loss, psi	0.88	0.70	0.68	0.83	0.37	0.27	0.20

Propeller-Compound

Meter size, in.	...	...	...	6/2	8/3	10/3	12/4
Pressure loss, psi	...	...	...	3	2.6	....	....

accuracy over the entire flow range; next come turbine-compound meters, and then propeller and propeller-compound meters. Even the latter, however, are more accurate than other classes of flowmeters, particularly over a widely varying flow range.

Because pumps must supply all pressure losses in the system, pumping power must be considered: to pump 1 gpm of water against a 1-psi head requires about 0.00058 hp. This seems insignificant until the flow rate and head losses mount up.

From a standpoint of given meter sizes, the vortex-velocity meter is the smallest, followed by the propeller meter, the positive-displacement meter, and the turbine and t-c meters, in that order.

METER FUNCTIONS

The two fundamental uses of velocity meters are data gathering and control. A wide variety of instrumentation has been developed to assist the meters in carrying out these functions under different situations.

Data gathering

Equipment here includes registers mounted directly on the meter housing, remote indicating registers, and/or recorders. All are used to integrate meter output in the form of spindle revolutions, and to indicate total quantity of liquid delivered. Registers of the reset type may be zeroed after delivery of a specified volume. Some have ticket-printing devices to record the quantity passed; others, in addition to their totalizing function, send out an electric impulse after a preset delivery. In all cases, the data gathered is used for accounting purposes and to check the delivery of raw materials and finished products.

The principal application of velocity meters in data gathering has been metering water for industrial or commercial use. They are so widely distributed for this purpose, even in a single city, that readings are generally taken from direct-connected registers. Lately, however, successful efforts have been made to apply velocity meters in other areas of data gathering. In chemical or food plants and at oil refineries it has become quite practical to use them at widely scattered points and transmit their data to a central control station.

Process-control functions

Here again the velocity meter closely parallels the positive-displacement meter. And capacity is the governing factor. Velocity meters perform control functions in such processes as water treatment, automatic titration, batch mixing, blending, packaging, etc. Their advantage here is that their mechanical output can be fed directly to the control device: there is no need to convert it to some other form of signal, as is the case with an orifice meter, for example, whose output is differential pressure.

In general, velocity meters have not been used in process-control applications as widely as positive-displacement types. Reasons are that many processes operate at relatively low flow rates, and less is known about the velocity type. In many instances venturi and orifice-type meters have been installed where velocity meters might have been the wiser choice.

Applying the IBM 704 to Milling-Machine Programming

In numerically controlled milling, the step between the parts drawing and the control tape is a long one, usually requiring a tremendous amount of computation. Today's trend is definitely toward making the job easier and less costly by using digital computers of both general- and special-purpose design to mechanize tape preparation. The authors describe techniques that permit successful application of a widely available general-purpose computer to the programming problem.

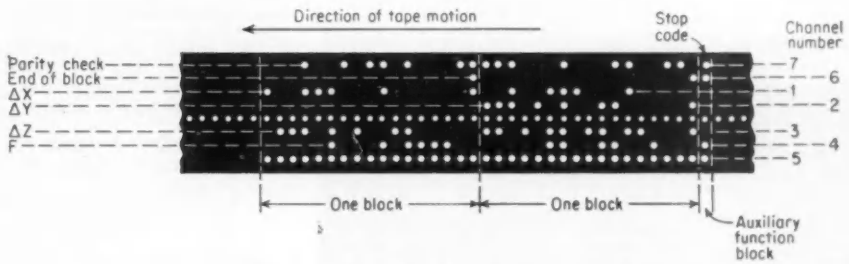


FIG. 1. Section of control tape for Bendix numerical control system.

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To understand the basics of numerical contouring, it is advisable to begin at what is actually the end-point of the process—the machine tool. A typical candidate for such control is a milling machine that has three axes of movement: longitudinal (table), transverse (tool slide), and vertical (tool slide). A servo drive powers the leadscrew associated with each axis. Moving the tool slide vertically brings the milling cutter into contact with the work. Then, by *continuously* controlling the transverse, vertical, and longitudinal leadscrews, cuts of any desired contour can be produced.

In the Bendix Tape Control System, which is the type in use at Georgia Lockheed, the input signals to the hydraulic servos are in the form of pulse trains. These pulses are generated by a control unit or director connected to the machine and equipped with a reader for processing the control tape, Figure 1. This tape furnishes discrete blocks of information, consisting primarily of X, Y, and Z movements, each accompanied by a feed rate value. The individual movements are given as numbers of pulses, each pulse representing 0.0002 in. of motion along an axis.

The machine control unit acts on one block of information at a time. This block is read into a temporary storage where it awaits completion of action on the previous block in active storage. From active storage, the binary numbers are transformed into pulse trains which feed the servos for all three axes simultaneously, at a rate dependent on the feed rate number in the given block.

It is seen that the control tape contains data for a series of straight line motions, one block being required for each line section. The length of a straight cut can vary from a few thousandths of an inch up to the full travel of the machine, depending on the degree of curvature in the workpiece. The greater this curvature, the more straight-line seg-

ments will be needed to produce a smooth, even contour. By making these segments extremely short, even sharp radii can be accommodated.

The data on the control tape originates on the parts drawing—and an enormous amount of computation is required to go from one to the other. To simplify the process (known as "programming"), techniques have been worked out that permit the use of high-speed digital computers. Much of the original investigations were conducted at MIT and involved the use of Whirlwind I (Ref. 1). In refining the MIT techniques, the authors have succeeded in making use of the more widely available IBM 704.

A special language that is recognized by the computer lets the programmer use conventional drawings for his source of information and requires him to do little or no calculation. This symbolic language is simple and easy to learn, and can be used to describe the part to be machined, the sequence of cuts, feed rates, cutting tools, and other necessary information.

TABLE I—Definitions

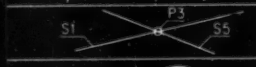
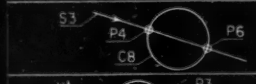
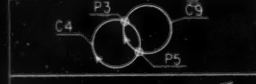
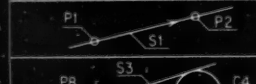
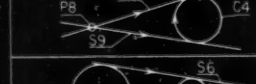
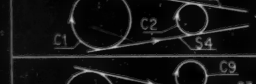
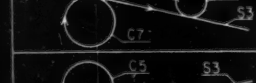
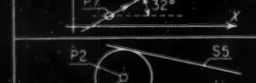
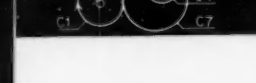
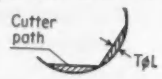
	A	B	C	D	E	F	G
Point by coordinates	P3	=		3.2		1.6	
 Point by intersection of two lines	P3	=		S1		S5	
 Point by near intersection of line and circle	P4	=	N	S3		C8	
Point by far intersection of line and circle	P6	=	F	S3		C8	
Point on circle, angle with X axis	P3	=		C7		21	
 Point by near intersection of two circles	P2	=	N	C4		C9	
Point by far intersection of two circles	P5	=	F	C4		C9	
 Line by two points	S1	=		P1		P2	
 Line, through point, tangent to circle	S3	=		P8	T	C4	
Line, through point, anti-tangent to circle	S9	=		P8	A	C4	
 Line, tangent to two circles	S6	=	T	C1	T	C2	
Line, anti-tangent to two circles	S4	=	A	C1	A	C2	
 Line, tangent and anti-tangent to two lines	S3	=	T	C7	A	C9	
Line, anti-tangent and tangent to two lines	S3	=	A	C5	T	C6	
 Line, through point, angle with X axis	S6	=		P7		32	
Circle by center and radius	C3	=		P2		1.8	
Circle by center, tangent to line	C3	=		P2		S5	
 Circle by center, tangent to another circle	C4	=		P8	T	C7	
Circle by center, anti-tangent to another circle	C1	=		P1	A	C7	

TABLE II—SPECIAL WORDS

1. *RIGHT, LEFT* are used to indicate that the tool is traveling to the right or left of the part looking in the direction of cutter movement. *RIGHT* or *LEFT* must be indicated before any initial cutting instructions are given, but need not be repeated until a change is desired.
2. *OFFSET* is the distance from the center of the cutter path to a specified edge and must be specified before any cutting instructions are given. The value of the *OFFSET* is placed in Column D on the same line.
3. T∅L stands for tolerance or allowable deviation. It is necessary to specify this deviation before the first circular cut is made. Thereafter, the same T∅L will apply to all circular cuts unless otherwise specified. Value of T∅L is placed in Column D.



Note: A T∅L is required because the spindle will move in straight line increments only. All circles must therefore be reduced to a series of straight line cuts.
4. *START* is indicated after the starting point is defined and before the first cutting instruction is given.
5. *END* is given to stop cutter motion at a particular point. The *END* instruction is always given in conjunction with an additional point in order to properly locate the cutter.
6. *UP* and *DOWN* commands are given to indicate motion in the Z axis with no motion in the X, Y plane.
7. *STOP* causes all machine functions to stop. This includes tape feed.

A	B	C	D	E	F	G
RIGHT						
OFFSET			0.50			
T∅L			0.001			
P1	=		-2.3		0.54	
START			P1			
END			P0			
180			UP			2.42
STOP						

TABLE III—CUTTING ORDERS

Cutting commands include feed rate and the point to which the cutter shall move. Feed rate is placed in Column A and the point in Column D. If the cut is along a circular path, then the specified path is indicated in Column F. Plus indicates clockwise travel and minus, counterclockwise.

Sequence of definitions and commands. When defining points, lines and circles, only points, lines and circles that have been previously defined may be used. For example, if P1 is defined in terms of S1 and S2 it is necessary that S1 and S2 be previously defined. This is important because the tape cannot be processed if undefined points, lines and circles are used in other definitions. Cutting instructions are executed in the sequence in which they appear.

Vertical motion is indicated in Colume G and takes place simultaneously with X and Y motion: plus for up and minus for down. Although Z motion is recorded only as a change in vertical position, the programmer should record the absolute Z coordinate in the "Remarks" column for his own information.

Rotation and translation of axis is indicated as follows: 32 deg rotation, translate (0,0) to (7.1, 5.6). Rotation or translation or both are often desirable where the part is dimensioned on the blueprint from reference lines that cannot be placed parallel to the machine axes. Rather than recalculate every dimension, it is possible to program the part in terms of the blueprint reference planes and then call for a rotation or translation as indicated above.

A	B	C	D	E	F	G
60			P5			
60			P6		+C5	
15			P3			-2.3
32			7.1		5.6	

The programmer simply prepares a manuscript similar to those shown on the accompanying table from information he reads off the print. Next, manuscript data is put on punched cards in coded form.

In a part description, points of tangency and other points of direction change may be defined implicitly (that is, in terms of other known data) and the explicit solutions left to the computer. The description is interpreted by the computer, which in turn provides solutions for data described implicitly, for coordinates of points defining the center of the cutter path, for reducing circular paths to straight line increments, for automatic slowdowns to prevent overshoot, and for a punched card output.

The output of the IBM 704 computer is a set of punched cards, punched in exactly the same format as the Bendix machine control tape. The cards, if laid end to end, duplicate the appearance of the tape in Figure 1. Thus, the conversion of cards to tape is a relatively simple matter. The converter designed at Lockheed uses an IBM card verifier and a Commercial Controls motorized punch. As the cards pass through the verifier, each hole in the card causes a hole to be punched in the corresponding channel of the tape. Total cost of the conversion apparatus was approximately $700.

The system is being used to produce tape for a Kearney & Trecker profiler with a Bendix control. It may, however, be used for other control systems by the addition of a computer output program to produce the data in the required form.

Language

The special language used to describe the milling operation consists of three types of statements:

1. *Definitions*—statements used to define points, lines and circles that will describe the path of the cutter in the milling operation. These are designated by a number prefixed by the letter *P* to represent points, S to represent lines, and C for circles. Table I is a summary of definitions.

2. *Special words*—statements that provide data such as the allowable deviation in approximating a circle by straight line increments, the cutter offset, etc. These special words are shown in Table II.

3. *Cutting instructions*—statements that describe the motion of the cutter. They furnish the feed rate and the next point to which the cutter will move. Straight line movements are assumed unless the instruction includes a circular designation.

To prevent ambiguity in definitions involving lines and circles, all lines and circles are given direction signs. The clockwise direction of a circle is designated as positive and the point of minimum X is always the starting point for determining Near and Far. Near and Far are used to distinguish between the two intersections that a line or a circle makes with another circle.

For a line, the choice of position direction is left to the programmer. The positive direction is that from the first point used (or implied) in the definition toward the second point. In the case of the point-angle definition of a line, the positive direction is taken from the point outward at the specified angle. Angles are measured from 0 to 360 deg, as in conventional coordinate systems.

Line and circle directions are employed to differentiate points of tangency. If the direction of the line is the same as the direction of the circle at the point of tangency, the line is tangent to the circle. If the directions are opposite, then the line is anti-tangent to the circle. Curves whose positive directions are the same at their point of tangency are called tangent. If their positive directions are opposite, they are called anti-tangent.

Inserting the instruction END indicates the completion of a sequence of movements. The point that is specified along with END determines the final position of the cutter; however, the cutter does not move to this point. It is necessary to complete a sequence of movements in the X, Y plane by use of END because the cutter position is always determined by the intersection of cutter paths approaching and leaving a particular point. The sequence may be interrupted by such commands as UP, DOWN, or STOP if subsequent commands continue the sequence of motions in the X, Y plane.

Slowdowns for the prevention of overshoot due to the momentum of the machine, and acceleration adjustments needed because of machine limitations, are automatically compensated for in the computer routines. The programmer need not consider these factors in the preparation of his manuscript.

Some typical cuts that occur frequently in milling work are shown in Figure 2 together with the manuscript instructions needed to describe them. The numbers in the first column indicate the step or sequence number; and for an actual piece these would run from 1 through possibly several hundred.

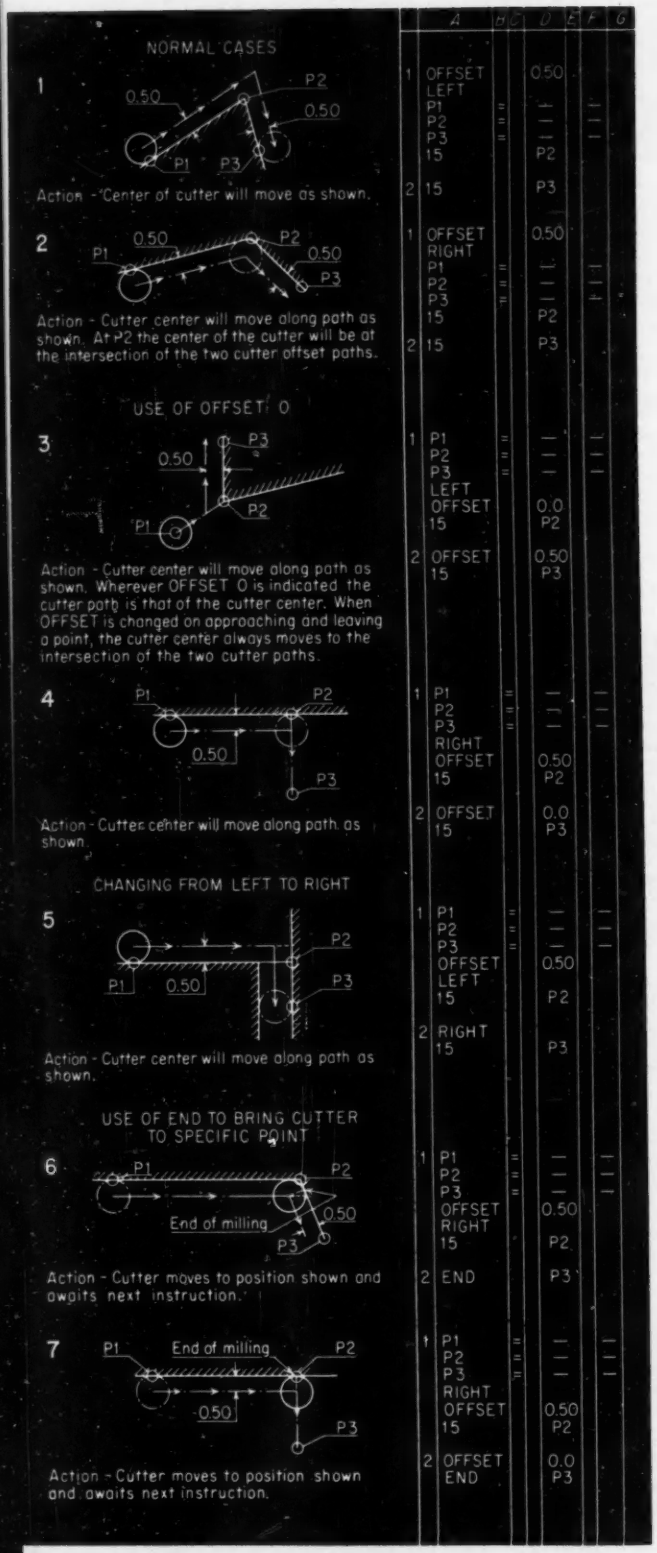
Computer program

After completion of the manuscript by the programmer, the information is transferred to decimal-coded punched cards. One card is used for each line of manuscript. The input cards are read into the computer, after which the program deck is run through. Magnetic tape stores the information on the input cards, while core storage holds the data from the program cards.

Next, the magnetic tape is read for definitions, which are identified by the equal signs. The form of the definition is then interpreted to determine the nature of the calculations required. For example, $P1 = N\ S1, C1$ calls for the solution of a line intersecting a circle, whereas $P1 = N\ C1, C2$ calls for a solution to the intersection of two circles. The distinguishing features are the S and C tags.

Points are stored by X and Y coordinates. Circles

FIG. 2–Manuscript descriptions for common milling cuts.



are stored by recording A, B, and C from the expression $x^2 + y^2 + Ax + By + C = 0$
Straight lines are stored by using A, B, and C from the expression $Ax + By + C = 0$
Since there is only one reading pass for definitions, a symbol must be defined before it is used in the definition of another symbol. When the tape reaches "End of File", all definitions have been read and points of intersection defined and stored. The tape is then rewound, ready to be searched for special words and cutting instructions. If errors in definitions appear, the operation halts at this point and the errors are printed out. Errors generally involve calling for impossible situations, such as describing a point as the intersection of two lines when the lines are parallel.

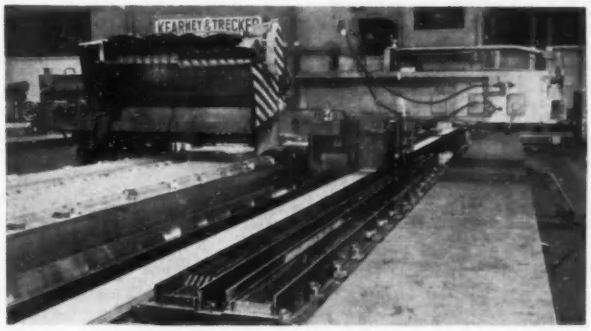
As the result of this first pass of the input tape, there are three tables in core storage: for points, lines, and circles. After this pass is complete, the input tape is rewound while the second part of the program is read into core storage, only two of the tables being preserved. The table of lines is no longer needed since at this time all definitions have been processed, and cutting instructions call for data on points and circles only.

The next part of the process includes the making of a printed list (on magnetic tape) of the values found for all points. The list shows any inconsistencies found in the definitions. If inconsistencies are present, processing stops. Otherwise, the computer proceeds to scan all cutting instructions and special words on the input tape. This includes calculating offsets, approximating circular cuts, and translating and punching tool orders (the information needed to move the cutter from one point to the next). This part of the program uses the table of points and the table of circles to determine explicit values for the symbolic information contained in the cutting instructions. The tool orders are punched as they are translated, so that at the completion of this pass on the input tape a complete set of punched cards is available for producing the tape for machine input.

In scanning the tape a second time, the reader passes over all definitions, i.e., those with an equal sign. The special words and cutting instructions shown on the flow diagram, Figure 3, are identified by their "spelling" and their position on the input card. For example, a number in columns 1 through 6 of the input card is always a feed rate value and signifies the beginning of a cutting instruction.

If circular cuts are indicated, the circle is approximated by a polygon, i.e., by a series of short, straight line cuts. The length of each cut is automatically determined by the allowable deviation from the true circle, specified by the special word $T\phi L$. The special words are more fully described above.

The offset cutter center location is then computed. This is the square called Set Up Straight Line Cut in the flow diagram. The output informa-



Cost Analysis for Numerically Controlled Milling

The computer techniques described in this article were given a practical test at Lockheed Georgia. In addition to proving the programming method, this test produced convincing statistics on the benefits to be gained from numerical contouring control.

The project involved the manufacture of 600 of the long plate cams needed for the skin mill shown here (a group of the cams are visible in the trough at the bottom center). A tracer-controlled milling machine formerly produced these cams. Now, a tape-controlled mill is used for the job. The 600 close-tolerance (plus or minus 0.002 in.) cams have been made at a savings of about $35,000 over the old method. The latter required 12 man-hours for laying out and filing a light-gage template, milling the cam on a tracer controlled mill, hand finishing, assembly, and inspection. By tape control, the time per cam was reduced to 4.65 man-hours, including about 0.8 hours per cam for preparing the manuscript and processing through the computer. The detailed operational analysis as given below does not include a materials saving of $1.50 per cam.

OLD METHOD: Tracer Controlled Milling from handmade 5:1 scale template.

Operation	Time, Hours	Labor Cost		Machine Cost	
		Rate/ Hour	Operation Cost	Rate/ Hour	Operation Cost
Saw Plate Stock to Width	0.2	$6	$ 1.20	$6	$ 1.20
Fabricate Template	2.4	$6	$15.40	$6	$14.40
Drill Tie Down Holes	0.2	$6	$ 1.20	$6	$ 1.20
Mill Profile	1.4	$6	$ 8.40	$8	$11.20
Burr & Identify Cam	0.3	$6	$ 1.80		
Lay Out Check Points	0.6	$6	$ 3.60		
Draw File to Tolerance	3.9	$6	$23.40		
Check with Height Gage	0.4	$6	$ 2.40		
Mill Length	0.6	$6	$ 3.60	$8	$ 4.80
Mill Slots or Chamfer	0.9	$6	$ 5.40	$8	$ 7.20
Drill & Ream Holes	0.4	$6	$ 2.40	$6	$ 2.40
Burr	0.3	$6	$ 1.80		
Remove Marking Ink	0.1	$6	$ 0.60		
Dichromate	0.1	$6	$ 0.60		
Oil for Storage	0.1	$6	$ 0.60		
Total per Cam	11.9		$72.40		$42.40

NEW METHOD: Numerically Controlled Milling

Operation	Time, Hours	Labor Cost		Machine Cost	
		Rate/ Hour	Operation Cost	Rate/ Hour	Operation Cost
Saw Plate Stock to Width	0.2	$6	$1.20	$6	$1.20
Drill Tie Down Holes	0.2	$6	$1.20	$6	$1.20
Burr	0.2	$6	$1.20		
Prepare 70E	0.3	$8	$2.40		
Prepare Input Cards	0.1	$8	$0.80		
Computer	0.05	$8	$0.40	$180	$9.00
Print Out	0.1	$8	$0.80		
Check Print-Out	0.1	$8	$0.80		
Prepare Tape	0.1	$8	$0.80		
Milling Profile-Cut to Length	0.3	$6	$1.80	$25	$7.50
Burr and Identify Cams	0.3	$6	$1.80		
Check Cams	0.8	$6	$4.80		
Mill Slots or Chamfer	0.9	$6	$5.40	$8	$7.20
Drill & Ream Holes	0.4	$6	$2.40	$6	$2.40
Burr	0.3	$6	$1.80		
Remove Marking Ink	0.1	$6	$0.60		
Dichromate	0.1	$6	$0.60		
Oil for Storage	0.1	$6	$0.60		
Total per Cam	4.65		$29.60		$28.50

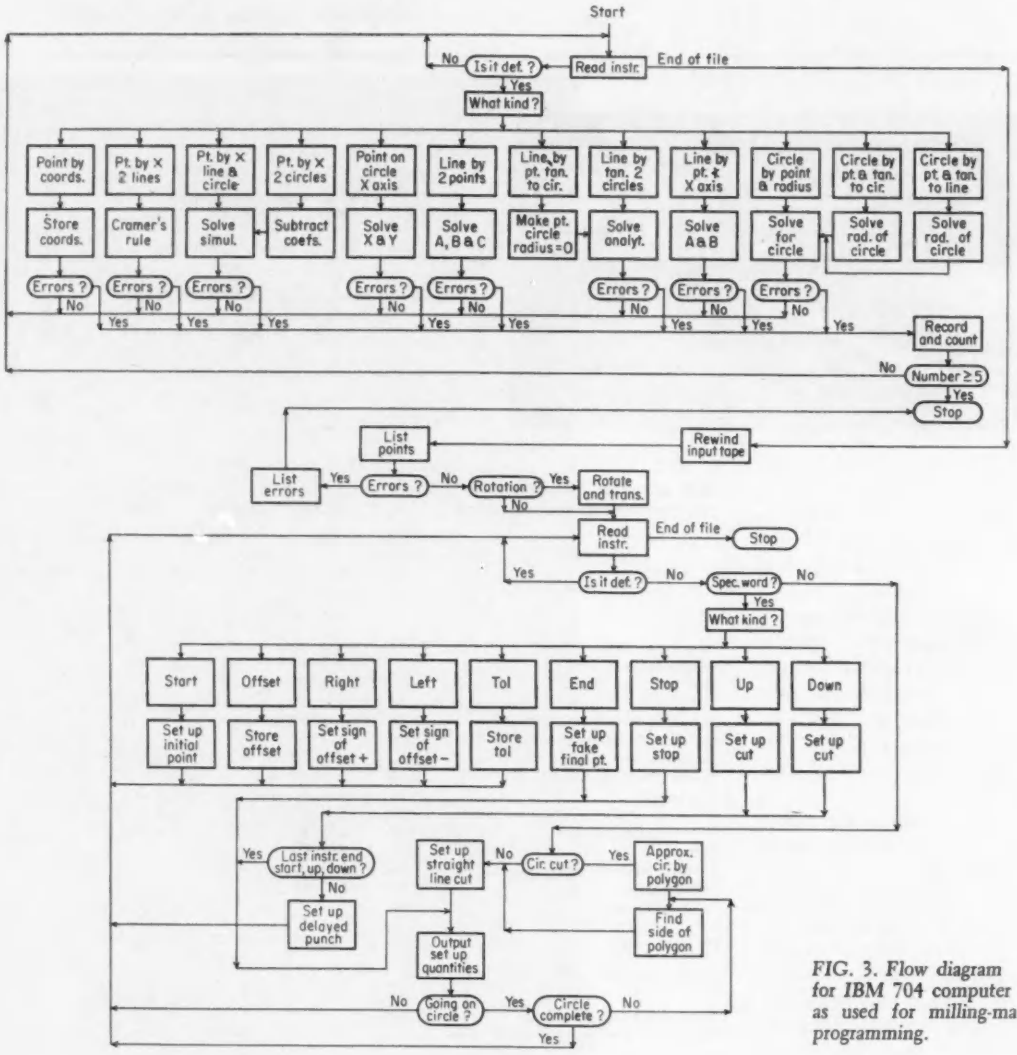


FIG. 3. Flow diagram for IBM 704 computer as used for milling-machine programming.

tion is punched as each successive cutter center location is computed. An additional computer routine in the output program automatically takes care of the milling machine's step-acceleration requirements and slowdowns to prevent overshoot. This is accomplished by examining the feed rate of the previous instruction and comparing it with the feed rate of the new instruction. If the difference exceeds 30 in. per minute, additional points are inserted at increments of 0.5 in., so that the feed rate may be increased or decreased in small steps. For example, if the machine starts from a stop position under a cutting instruction asking for 120 in. per minute, the computer will insert three additional points in the cutter path. The feed rate will be 30 in. per minute to the first point, 60 in. per minute to the second, 90 in. per minute to the third. At the third point the rate of 120 in. per minute is attained.

Additional points, for the prevention of overshoot, are also inserted into the cutter path. At the end of each straight line travel, the computer examines the angle of direction change. Using the allowable deviation stored in $T\phi L$ and a table of overshoot values for different feed rates, the computer inserts the additional points to decelerate to an acceptable turning speed.

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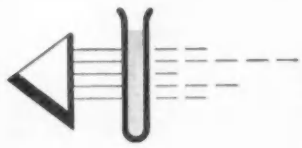


Controlling Fluid Processes With CONTINUOUS VISCOMETERS

The objective of viscometry is to assure product performance rather than composition. The measurement of viscosity is not in the usual sense a specific analytical measurement, such as would be obtained with infrared analyzers and chromatographs; but a large variety of commercial products are controlled directly or indirectly by a viscosity measurement, and the greatest number of these contain dispersed solids. It is only rarely that operating departments desire an analysis of such colloidal materials for a specific compound or element. Interest is usually in the measurement and automatic control of interactions of broad groups of components, and for such applications continuous viscometers have proved invaluable.

ALAN BEERBOWER
Esso Research & Engineering Co.

The first intelligible definition of viscosity is credited to Isaac Newton, who described viscosity as a constant force resisting movement of liquid between parallel planes. Here the planes are of unit area, are separated by a unit-thick layer of liquid, and are moving relative to each other at unit speed.

A more practical definition is that of Poiseuille who described viscosity in modern terms as the ratio of shearing stress to rate of shear at the wall of a tube. Mathematically:

$$\eta = \frac{\frac{PR}{2L}}{\frac{4Q}{\pi R^3}} = \frac{\pi PR^4}{8QL}$$

where P is pressure, R is radius, L is length, and Q is flow rate by volume. In cgs units, η is given in poises, the absolute unit of viscosity. (Centipoises are more commonly used for convenience.) The viscosity of water at 68 deg F is one centipoise. Closely related are the kinematic viscosity units of stoke and centistoke, the viscosities obtained by expressing Q in mass flow rate. Hence, centipoise equals centistoke times density. Unfortunately, these relationships apply only to simple Newtonian liquids, wherein the viscosity is a constant at any given temperature. Curve 1, Figure 1, shows the linear viscosity characteristic for Newtonian liquids.

Most other liquids are colloidal, and show a variation in viscosity with rate of shear or some other mechanical variable; hence they are classified as non-Newtonian. The study of the flow of non-Newtonian materials is known as rheology. Such materials include several distinct varieties:

1. Bingham plastic materials, which are defined as having a "yield value" or minimum shearing stress $PR/2L$ before any movement takes place, Curve 2, Figure 1. Above this, stress flow is Newtonian. True Bingham materials are rare and perhaps even nonexistent; most products of this type are "pseudo-plastic" as is shown by Curve 3 in Figure 1. Plastic-type materials often exhibit a secondary effect known as thixotropy. This is a temporary loss of yield value—due to working or movement—which is recovered on standing.

2. Dilatant materials, which tend to increase their viscosity under flow, and may even approach a limiting rate of shear due to thickening, Curve 4, Figure 1. Such materials usually contain rather coarse par-

FIG. 1. Curves showing behavior of typical Newtonian and non-Newtonian viscous materials.

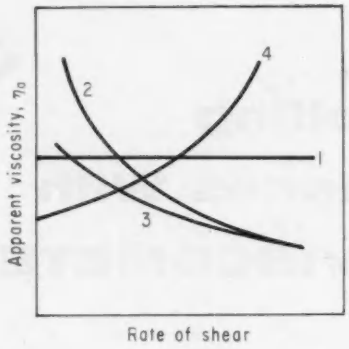


FIG. 2. The apparent viscosity vs. shear rate depends on the type of material.

ticles in suspension. The thickening caused by flow, and lost on standing, is called rheopexy.

3. Visco-elastic materials, which tend to follow the pseudo-plastic pattern of Curve 3 in most viscometers. Their rubbery property can be suitably measured by instruments other than viscometers.

In all non-Newtonian materials, the viscosity calculated from the Poiseuille formula is not a constant, but a variable known as the apparent viscosity, η_a. Typical curves in Figure 2 use the same line numbers as in Figure 1. The Newtonian fluid, of course, has a constant viscosity. The Bingham-type (line 2) varies in apparent viscosity from infinity at zero rate of shear to a constant at high shear rates approaching the viscosity of the liquid phase. The pseudo-plastic material is similar, but starts to flow at a finite viscosity (line 3); the dilatant material (line 4) shows an increasing apparent viscosity.

The concept of apparent viscosity has been considerably criticized in recent years as implying that a single measurement gives a picture of the rheological properties of a material. It is quite true that a non-Newtonian fluid must be characterized by two parameters, such as the yield value and the viscosity of the liquid phase. However, no harm can be done by expressing the result of a determination as "apparent viscosity" if the rate of shear is reported—particularly when the latter has been wisely selected.

Practice of viscometry

In a viscosity application, the nature of the material being tested must be known. In certain simple mixtures, a determination of a Newtonian viscosity will actually reveal a chemically specific result. The glycerol content of a glycerol and water solution, for example, may be determined quite accurately by measuring this viscosity. It should be recognized, however, that composition can generally be correlated with several other properties which are easier to measure; in the glycerol-water system, density or refractive index would be a better control. In other cases, such as blending two components (syrup with water, or light with heavy lubricating oils), the "specific" result would be the percentage of the more viscous component. This information may be of direct value, but more often is primarily a means of meeting customer specifications for product viscosity.

In many applications, the viscometer results are completely nonspecific, even for Newtonian fluids. Control of an oil distillation process, where a few hundred thousand out of millions of molecular species are being concentrated in one cut, is one example. Others are the bodying of oils, resins, and asphalts and multicomponent blending.

Non-Newtonian products are generally tested for their suitability in application; the composition is of secondary interest. The plant engineer may devise empirical charts—showing the water content of a food product, or the soap content of a grease, as indicated by viscosity—and obtain useful information. Here again, however, easier methods are available and viscosity control simply insures that mysterious and elusive "body", "texture", "feel", or "tack" of such materials as paints, adhesives, and inks, food products, and lubricants.

Also highly important in viscosity control is the instrument to be used. Viscometers for laboratory control work are, in general, stylized miniature versions of the equipment in which the product is to be used or made. Hence these types have evolved:

- the efflux viscometer, representing a gravity flow tank with an outlet pipe
- the rotary viscometer, resembling a bearing and shaft, and sometimes a small mixing kettle
- the falling-ball (or rising-bubble) viscometer, representing separation in storage, and
- the pressure-type viscometer, resembling a pumping system

Most of these instruments yield results calibrated in arbitrary units that may be converted to kinematic or absolute viscosity units. A special case is the Fischer & Porter variable-area Viscorators, which report in kinedynamic units, *KDU*, a complex function of viscosity, fluid density, and float density. Other variations are the two vibratory-type viscometers, the Ultra-Viscoson (centipoises times density), and the Fitzgerald (a dual result, including compliance and shear modulus). Some arbitrary units, such as Saybolt Universal Seconds, are commonly converted to kinematic values.

Each viscometer group except the efflux type has contributed one or two instruments for continuous plant control applications. The five leading exam-

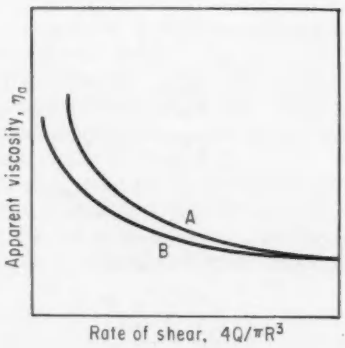
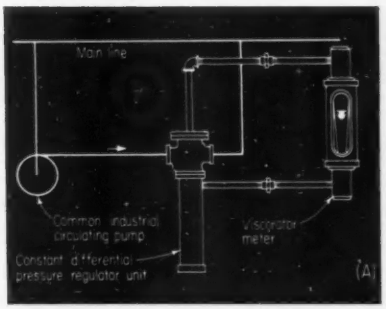


FIG. 3. The behavior of two different materials shows that the rate of shear must be controlled to determine a meaningful apparent viscosity.

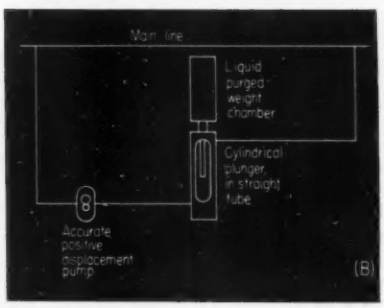
TABLE I

WHAT'S AVAILABLE IN VISCOMETERS FOR PROCESS CONTROL

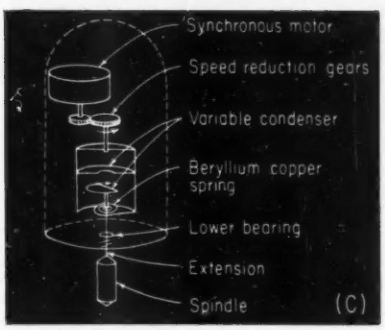
VARIABLE-AREA VISCORATOR
Fischer & Porter Co.
Hatboro, Pa.



CYLINDRO-PLUNGER VISCORATOR
Fischer & Porter Co.
Hatboro, Pa.



The falling-ball principle is represented by the Fischer & Porter Viscorator, which is available in several modifications. The "falling" ball is a float, supported by a rising column of liquid. A magnetic system reports the float position continuously. The principal types are taper-tube models, in which the float rises until the annular space is large enough to allow escape of the fluid at constant rate (Figure A), and a straight-tube cylindrical-plunger model, in which the length of plunger in the flow stream is the measured factor, Figure B. The latter is still in an experimental state. The Viscorator has an uncontrolled low-to-medium rate of shear.



VISCOMETRAN
Brookfield Engineering Co.
Stoughton, Mass.

A rotary viscometer is the Brookfield Viscometran, Figure C. The rotary element is selected for range, and the speed of rotation is chosen at the time of installation. Continuous readings are reported electrically, from a spring torque-meter, in terms of angular displacement as measured by a variable capacitance. This viscometer has a controlled low-to-medium rate of shear.

NORCROSS VISCOMETER
Norcross Corp.
Newton, Mass.

A pressure-type instrument is the Norcross viscometer, Figure D. The pressure is provided by the weight of a piston, and the time for the escape of a fixed volume of liquid through the annular space between the piston and wall is recorded. Operation is intermittent, dead time being required to recharge the sample cup during the lift stroke of the piston every one or two minutes. Though superficially an efflux type, the Norcross operates on piston weight and so reads in absolute viscosity rather than kinematic. A special recorder receives the time of fall data and can be set to smooth the record electromechanically, giving a continuous control signal with a long time constant. The instrument has an uncontrolled low rate of shear.

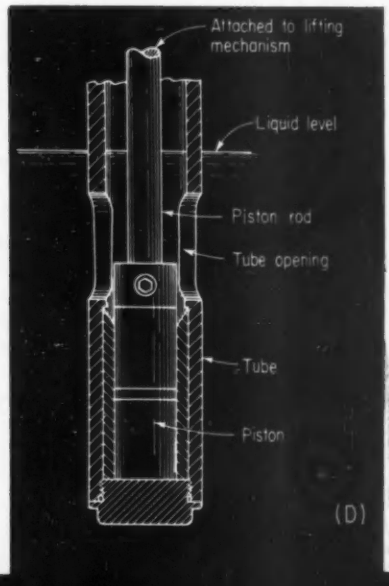
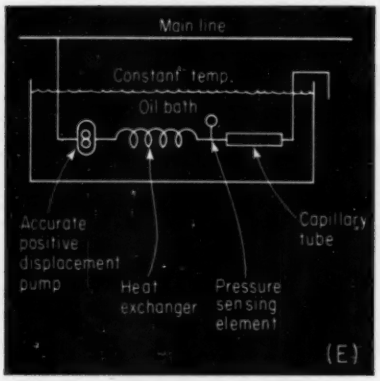


TABLE I cont.

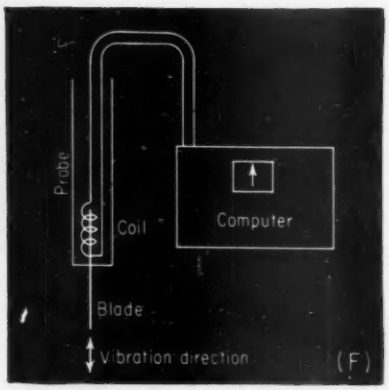


HALLIKAINEN VISCOMETER
Hallikainen Instruments Co.
Berkeley, Calif.

Another pressure viscometer is the instrument currently marketed by Hallikainen, Figure E. Several instruments of this type have been built by the American Instrument Co. for the Esso Standard Oil Co. under the patent held by Esso Research & Engineering Co. Operation is continuous; it consists of passing the measured fluid from an accurate metering pump through a capillary tube, the pressure differential across the capillary being directly proportional to the absolute viscosity. Strain gages or transducers convert the pressure differential to an electrical signal, if that is the type of signal desired; if a pneumatic signal is wanted, a pneumatic transmitter can be used. The rate of shear and range can be varied independently from low to high values by changing the pump speed and the capillary dimensions. Hallikainen recommends its instrument mainly for Newtonian fluids, but Esso employs its models in non-Newtonian fluids, too.

ULTRA-VISCOSON
Bendix Aviation Corp.
Cincinnati, Ohio

The vibratory type is the Bendix (formerly Rich-Roth) Ultra-Viscoson, Figure F. This instrument differs from all others in that the fluid is not permanently displaced but merely oscillates. The sensitive element is a thin metal strip resonant in the axial direction to a frequency of 28 kc per second. A pulse of this frequency is sent out periodically and its decay rate measured. The decay rate is a function of the product centipoises times density. The pulse rate varies with the decay rate, and ranges from 50 per second in air to 5,000 per second in 50,000 cp times d fluid. These factors are integrated in a small computer and reported as a steady electrical reading. The rate of shear on such a system cannot be calculated, but it is known to be very high at the center of a cycle and zero at both ends.



ples are listed in Table I. All are accurate, have recordable signal output, and are able to operate fully automatically in a variety of systems.

Design of a plant viscometer system

The first concern in the choice of an instrument is whether the material it is to handle is Newtonian. For true Newtonian fluids, the five instruments listed in Table I are all applicable, and the choice must rest on other grounds. However, for non-Newtonian products (the majority of cases), some control of rate of shear is desirable. Figure 3 shows two pseudo-plastic fluids of slightly different flow characteristics; at an uncontrolled shear rate, both can give the same apparent viscosity. This is easily detected in the laboratory by obtaining readings under enough different rates of shear to establish the curve shape; in the plant, however, the rate of shear must be preselected.

This rate can be set at a predetermined value in the Esso or the Shell-Hallikainen viscometer, and in the single-float and Cylindro-plunger Viscorator (where the pump rate and capillary radius can be varied). The Viscometran rate of shear is set by rotor radius and rpm, with some consideration of the spacing of the shield tube which normally surrounds the rotating element. The Norcross viscometer operates on a constant shearing stress basis, as illustrated in Figure 4. Here η_a becomes infinite below the yield values C and D for fluids A and B. The Norcross has been successfully used, at a stress value such as E, in a large number of non-Newtonian applications where the yield value is small.

Materials measured by the variable-area Viscorator must have small yield values too, but here the shearing stress ($PR/2L$) varies also with the apparent viscosity. This is due to the increase in radius R as the float rises in the tube. Such a situation limits the Viscorator's application to Newtonian fluids in general, and to non-Newtonian ones of less than 500 cp apparent viscosity. The Ultra-Viscoson can be used with non-Newtonian fluids in some cases, since its shear rate does not depend on the fluid, but the results must be regarded as empirical. At the very high shear, there may be unexpected results; for instance, greases normally thought of as thixotropic may prove to be rheopectic.

A factor not always sufficiently emphasized is temperature control. Temperature affects viscosity far more than it does any other fluid property. Most fluids follow the Walther equation

$$\log \log (K - 0.06) = A - m \log T$$

approximately, where K is centistokes, T is deg Rankine and m is the ASTM slope. The m factor can be measured by plotting viscosity vs. temperature on chart ASTM-D-341-43, and measuring the negative tangent of the angle from horizontal of the resulting straight line or, if greater accuracy is needed, the tangent to a curve at the point of interest. Table II shows the rather small temperature change needed to double or halve the viscosity for typical Newtonian fluids. Because of this high sensitivity, temperature control on Newtonian viscometers in the laboratory is normally 0.1 deg F, and often 0.02 deg F. Non-Newtonian materials may not require such close control, since apparent viscosity is due partly to a dispersed solid, which is unaffected by temperature. The accuracy desired may also be appreciably less in plant applications.

There are several ways to accommodate temperature variations. If the entire process stream is already subject to the necessary temperature control, little has to be done. But if it is not, a side-sample may be separately conditioned in a heat exchanger. This is rather cumbersome, however, and introduces an undesirable control lag (dead time) due to time lost in the conditioner.

The most efficient way is to measure the temperature continuously and use the resulting signal to compensate the viscosity to a reference temperature. Bendix, in cooperation with Esso Research & Engineering Co., has done a great deal to perfect this approach. Fischer & Porter also has an excellent temperature-compensating system. Both are recommended for a range (from nominal temperature) of plus or minus 50 deg F, though the Bendix system is reportedly limited to a range of plus or minus 20 deg F in high slope cases. Norcross also offers temperature compensation, but only to plus or minus 5 deg F. Brookfield is reported to have a system under development, while Esso and Shell-Hallikainen depend upon conditioning of a sample stream—though presumably compensation could be applied here, too. Only Fischer & Porter uses the ASTM equation discussed above, which has a proven working range of plus or minus 200 deg F. Bendix and Norcross use a linear equation.

Still another method is to record the temperature and look up the correction on a chart. Any type of problem can be handled this way, but it is cumbersome, permits error, and is essentially a barrier to full automatic control. Still, it is believed to be the only feasible solution at the present time to problems of variable ASTM slope, which all systems assume constant for a given material. This situation may arise in polymer solutions.

Another consideration is to protect the instrument against plugging or caking. The Viscometran and Norcross are essentially self-cleaning, as is the Viscorator in the variable-area models. The Cylindro-plunger model, however, uses a positive displacement pump, as does the Esso and Shell-Hallikainen designs. These pumps require careful straining of the fluid. And in addition, the Ultra-Viscoson must be protected from gummy particles which tend to plate out on the blade.

The problem of sampling is one that is too often neglected. The cheerful assumption of turbulent flow with good radial mixing is never justified in highly viscous material. Analysis of Poiseuille's equation shows that the surface layer, particularly in the case of pseudo-plastic materials, is essentially a permanent and stagnant part of the pipe. The existence of this stagnant layer has been confirmed by the use of radioactive tracers. Hence, surface sampling is almost always wrong.

The ideal way to sample is to pass the entire process stream through the viscometer, an operation most easily accomplished by the Fischer & Porter variable-area instrument. All the other instruments (except the Esso or Shell-Hallikainen types), if inserted in the center of the pipe through a tee at a bend, can approach this ideal, provided the stream is homogeneous. But it is important to have adequate velocity to sweep the probe clean. A minimum velocity of 25 ft per min is recommended, but this will vary with the material and temperature. The Ultra-Viscoson actually tests a layer only a few microns thick on its blade, and must be handled accordingly. To sample batches, the Norcross, Viscometran, or Ultra-Viscoson probe is put directly into the kettle. For flow-line service, the Viscometran must be air-purged to keep fluid out of the motor housing.

Where side-stream sampling is a must because of temperature control or the need to use a Hallikainen-type instrument, a pitot tube sampler (or a bevel-end tube extending to the center of the line) is required. Kettle sampling for the Viscorator or Hallikainen can be done on a pumping-over line.

Control of response speed is an intimate part of sampling and temperature control. In some applications, such as where the sensing element is directly

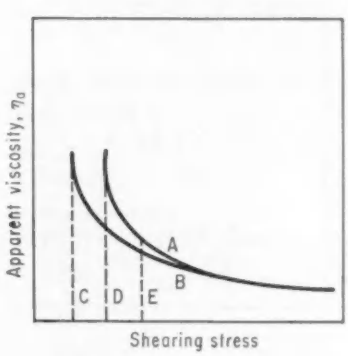


FIG. 4. Some viscometers operate at a constant shearing stress, which must be near the yield value where the curves diverge.

in the process stream and where rate of shear is not important, no response-speed problem exists: the fluid already flows at maximum speed when the viscometer is properly set up. But in other applications, particularly those using a temperature conditioning heat exchanger, there is an appreciable lag. The exchanger must be designed for maximum area and minimum volume, and when the viscosity of pseudo-plastic fluids is being measured, all the exchanger's parallel flow paths but one will inevitably plug. Thixotropy also contributes to response lag: such materials must be worked consistently and uniformly at low flow rates.

Still another contributor to lag, associated directly with non-Newtonian fluids, is the need to control shear rate. The curves in Figure 3 illustrate typical convergence at high shear rates and indicate the importance of using the lowest shear rate practicable. Most materials are judged by the consumer at very low shear rates by "feel", regardless of their end use. In fact, the yield value at zero shear rate may be that variable for which viscosity is measured. This places a handicap on the Cylindro-plunger Viscorator and Esso or Shell-Hallikainen instruments in terms of lag time, for both must operate at low flow rates, and their shear radii or clearances must be large. They thus suffer from large dead time and a low scale reading. However, the readings can be built up in the Esso or Shell-Hallikainen unit by increasing capillary length at the expense of dead time. Increased length increases the volume, and volume divided by the flow rate equals dead time. The Viscorator can be made more sensitive by decreasing the plunger loading—without sacrificing response time. A compromise is required, and must be worked out for each case, but the response time should be sacrificed only as a last resort.

With the instrument and its sample system set up, a signal is available. The first step is to multiply this signal by the temperature-compensating factor if it, too, is available. The signal may then be recorded, using such techniques as zero suppression and scale expansion, which are permissible because the signal is usually low in noise content (although some pump noise may appear in the Esso or Shell-Hallikainen instrument). A transducer then provides an output control signal, which may be used to add more diluent, stop the heating cycle, or do whatever else is required for a particular application.

TABLE II. HOW VISCOSITY VARIES WITH TEMPERATURE

ASTM slope	Type of fluid	Temperature change to double or halve the viscosity	
		From 5,000 to 10,000 cp	From 100 to 50 cp
1.0	Aromatic tar	minus 8 deg F	plus 19 deg F
0.7	Lubricating oil	12	27
0.4	Silicone oil	21	50

Viscometer installations

CONTROL OF A CONTINUOUS GREASE PLANT: Grease is made by mixing soap and oil, the resulting viscosity depending on the ratio of these components. A typical continuous grease plant is now under control of an Esso viscometer. This viscometer, essentially similar to the Shell-Hallikainen type, is unique in that it handles highly viscous non-Newtonian greases. The capillary is of 0.230 cm radius and the flow rate is 0.939 cc/sec, giving a rate of shear of 97.9 reciprocal seconds. This small rate correlates with yield value (measured as ASTM worked penetration). The coiled capillary is made especially long (311 cm) to build up pressure. The pressure differential is measured by strain-gage transducers and the result recorded on a Foxboro Dynalog instrument. Temperature control is by an American Instrument Co. thermostatic oil bath held at 175 deg F plus or minus 0.2 deg F. This temperature was selected because it is at the half-way point in the main-line temperature range of 165 to 185 deg F, and so minimizes the temperature conditioning problem. Passage through the pump, a Zenith Model No. 3, was sufficient to bring the grease to 175 deg F plus or minus 0.5 deg F, and the long capillary made the final temperature adjustment in its first few inches. Hence, no heat exchanger was required.

Operation for the past nine years has been satisfactory. The worked penetration at 77 deg F can be predicted to about plus or minus 10 points, or the soap content of the grease within plus or minus 0.5 percent. Automatic control has not been considered worthwhile.

MONITORING OF MOTOR OIL CANNING: At a motor-oil canning plant an error in the oil supply system could result in the wrong product being canned. Laboratory control is of little value because it takes so long to get results; the time spent in drawing a sample, running it to the laboratory, and returning to the plant with the answer adds up to about an hour. The Esso plant at Baltimore cans 450 quart cans per min. This means that 27,000 cans might have to be opened and dumped—a very depressing chore. To prevent this, a Bendix Ultra-Viscoson was installed in each of two canning machine reservoirs. Resistance thermometer elements feed a temperature signal back to a Bendix Automatic Temperature Compensator. The compensated viscosity signal then goes to a standard 0-25-mv circular-chart recorder-controller, with a special chart reading in centipoises times density. Oil from tankage, at a temperature of 40 to 90 deg F, is pumped to the reservoirs from which the cans are filled. The foreman resets the control limits and the slope dial for each of nine oils handled by the machine.

Performance has been excellent. No actual pumping errors have been detected in the six months of operation, and simulated emergencies have resulted in immediate shutdowns.

Pulse Code Modulation Has Advantages

THE GIST: Data transmission involves the problem of recognizing a signal in spite of noise introduced by measurement and transmission devices. Pulse transmission systems all share a real advantage in that a pulse of sufficient amplitude is readily recognizable in the presence of wide-band noise. Pulse code modulation adds the ability to transmit a signal of any required accuracy without deterioration by noise, and with very small increases in transmission power. PCM requires more bandwidth.

FRANCIS J. ENGE,
American Machine & Foundry Co.

Various types of carrier modulation techniques have been used for data telemetry, by wire and radio, because they permit transmitting the lowest frequencies, even down to dc, with no loss in accuracy. By far the best of all modulation techniques, especially with regard to signal-to-noise ratio or transmitter power to output noise ratio, is pulse code modulation (PCM). Its single theoretical disadvantage is that it requires somewhat more bandwidth than other types to transmit a signal with a given highest frequency component. But this disadvantage becomes less and less important as carrier frequency increases. Microwave telemetry links have used the 215-225 megacycle band, and are moving up to 2,200 megacycles, where bandwidth is cheap.

The advantages of PCM derive basically from the relative ease of detecting a (binary) pulse of sufficient amplitude in the presence of wide-band noise. Other pulse transmission methods share this advantage.

Signal-to-noise ratio of pulse transmission

Detection of a pulse or recognition of its absence requires a definite signal-to-noise ratio at the detector. Then, if the signal, when sampled, exceeds some preestablished value, E, a pulse is present, and if it is less than E, there is no pulse. But there is this complication: if the noise at the time of sampling exceeds E in the proper polarity, an error will develop. With a Gaussian noise distribution (uniform power spectrum) the probability of such an event is proportional to the complementary error function of

$$E/a = (P/4N)^{1/2}$$

where a is the rms noise amplitude, P is the pulse power, and N is the noise power in the band.

Note that as P is increased, this function decreases very rapidly, so that if P/N is large enough to make the signal intelligible, only a small increase will make for practically perfect transmission accuracy. The table illustrates the effectiveness of small increases in P/N when the threshold has been achieved (Ref. 1).

It is clear that a definite threshold exists, at about 20 db P/N, below which channel fluctuation noise degrades the transmission, and above which it has almost negligible effect.

Pulse code modulation, as stated before, shares this signal-to-noise property of pulse detection with other pulse transmission methods. But PCM has this further advantage over pulse-amplitude, -phase,

PULSE DETECTION PROBABILITIES

P/N (db) pulse power to rms noise power	Probability of error	For pulse frequency of 100 kc., this is about one error every
13.3	10^{-2}	0.001 sec
17.4	10^{-4}	0.1 sec
19.6	10^{-6}	10 sec
21.0	10^{-8}	20 min
22.0	10^{-10}	1 day
23.0	10^{-12}	3 months

or-width modulation systems: the signal detector at the receiver is digital, and not analog, in nature. The signal can therefore be received and detected to any precision desired simply by increasing the number of code bits which represent a single sample of the input signal. The price paid is bandwidth, but the precision of the received signal improves exponentially as transmitter power is increased linearly.

Theory of PCM

To understand the statements just made, consider the effects of coding the number 9,900 in straight binary fashion. The binary code for 99, i.e.:

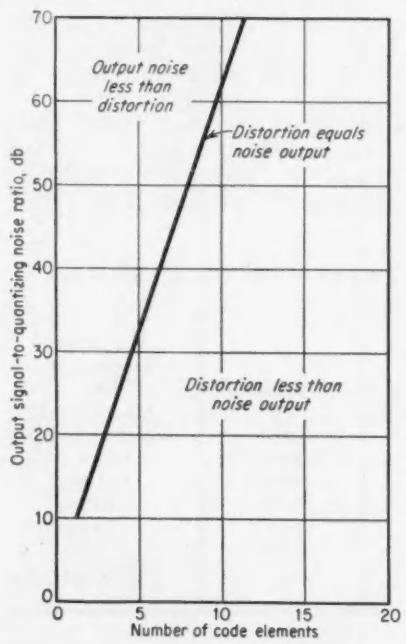
1100011

can be used if it is understood that it represents the number of "hundreds". To write the number 9,931 in the same code, however, requires seven more binary (code) places:

10011011001011 = 9,931

Only discrete values of the information can be transmitted by the code, since in the process of coding the signal must be quantized, or digitized, to the nearest discrete value which can be transmitted by the code. The difference between two adjacent discrete values is called a quantum, and the greatest error inherent in quantization amounts to half a quantum step (Ref. 2). This error is called quantization error, or quantization noise. It arises only from the quantization before the initial transmission, and is not augmented by transmission and relay, regardless of the number of relays used in the transmission.

FIG. 1. Signal-to-quantizing noise ratio vs. number of binary code bits in PCM transmission.



The output signal-to-quantizing noise ratio is relatively independent of the number of code digits so long as the number of digits exceeds three. Figure 1 illustrates the relation, showing the number of digits for which the output noise power is equal to the distortion power when a definite input or output signal-to-noise ratio is assumed (Ref. 3).

To determine the bandwidth which a pulse code system will require, the sampling principle must be understood. Data to be transmitted is usually an analog signal. It may be a complex voice wave, a fairly steady voltage output from a strain gage, or any other continuous function. The sampling principle specifies the minimum number of discrete values (samples) of the analog function necessary for its complete and unambiguous definition.

According to sampling theory, all the information of the original signal can be synthesized if two things are known: the instantaneous magnitude of each sample, and the instant at which the sample is taken within each subinterval, T, of time, where T is less than one-half the period of the highest frequency present in the signal, and only one instantaneous sample is taken for each subinterval. That is, by sampling at the rate of $2B$ samples per second (where B is the maximum frequency component of the sampled function) with unit impulses centered about the sampling instant, the original signal wave can be reproduced by multiplying each unit impulse by its coincident sample, dividing by the rate of sampling, and applying the resulting array of impulses to an ideal low-pass filter of cutoff frequency equal to B (Ref. 4).

With this principle, it is not necessary to transmit the entire continuous function of time to transmit a band-limited signal of duration t, but only the finite set of $2Bt$ independent values obtained by sampling.

Thus, transmission of exact instantaneous amplitudes at intervals spaced $\frac{1}{2}B$ apart would permit perfect reproduction of a signal. But it is impossible to transmit the exact amplitude of the sample because of the quantizing error. Once in quantized form, however, the signal can be relayed for any distance through repeaters without loss in quality, provided only that the added noise in the signal received at each relay is not too great to prevent correct recognition of the particular level each given signal is intended to represent.

In a binary PCM system, for the same simultaneous variation of bandwidth and power, the ratio of peak-to-peak signal to rms quantizing noise, R, is given by:

$$20 \log_{10} R = 6n + 10.8 \text{ db}$$

The sampling principle has shown that in order to transmit a signal of maximum frequency B by PCM, $2B$ code groups per second must be transmitted, with each code group containing n code elements or pulse places, the number n being deter-

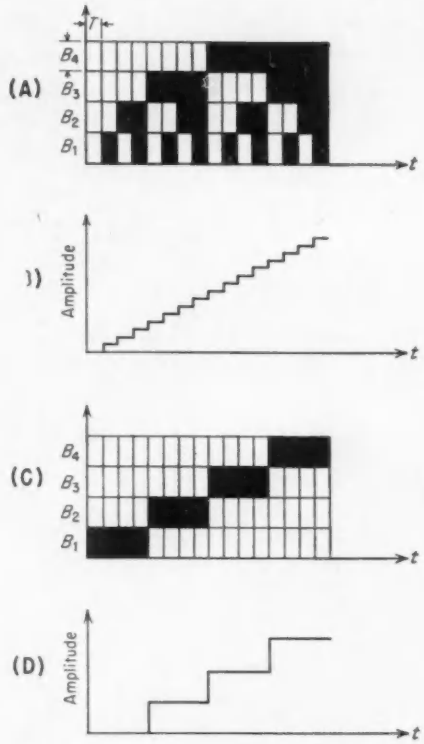


FIG. 2. A—Four-bit code transmission of linearly rising signal; B—Output of pulse-code system shows quantization noise introduced by four-bit code; C—Changing only one bit at a time produces: D—One fourth the signal-to-noise ratio and a much poorer representation of original signal.

mined by the resolution (accuracy) required of the system. Therefore, what is actually called for is $2nB$ pulses per second, which will require a transmission bandwidth of nB. That is, the total bandwidth required for PCM is theoretically n times as great as that required for the direct transmission of the signal, where n is the number of code elements in the code group. Multiplex transmission using either time or frequency division may be used, but in either case, the total bandwidth will be the same.

Bandwidth varies directly as n. It has also been shown that the precision of the system, which can be expressed as signal-to-quantizing noise ratio, is an exponential function of n. Therefore, PCM is capable of trading bandwidth for signal-to-noise output ratio more efficiently than any other known system, and can provide any desired output signal-to-noise ratio by the simple expedient of making proper use of increased bandwidth.

An extraordinarily clear picture of this is given by Oliver, Pierce, and Shannon (Ref. 1). They consider a simple PCM system in which four binary digits are transmitted on four adjacent frequency bands, with powers just sufficient to override noise. In Figure 2A, the signals in these four channels, B_1, B_2, B_3, and B_4 are shown vs. time. A black rectangle represents a pulse; a white rectangle the absence of a pulse. The rectangles are $T = \frac{1}{2}B$ long. The sequence illustrated represents a quantized approximation to a linear change of amplitude, with time as shown in Figure 2B. When a pulse is sent in only one channel at a time, as shown in Figure 2C, the quantized representation of the signal is shown in Figure 2D. The number of levels is four, whereas in 2B there are 16. Thus 2B represents four times as good a signal-to-noise ratio as 2D.

The total energy transmitted in each is represented by the total black area. On the average, twice as much power is used in 2A as in 2C. Thus, the signal-to-noise ratio has been increased by 12 db with a power increase of only 3 db by sending the signal via method 2A rather than 2C. Using six channels instead of four would have produced a signal-to-noise improvement of 21 db for a 4.77 db increase in average power. The greater the number of channels used, and hence the wider the frequency band used, the better the method of transmission represented by Figure 2A as compared to that represented by 2C.

Figure 2A represents PCM, while 2C represents, essentially, quantized fm with sampling. In 2C the signal varies with frequency according to the amplitude of the signal, and in addition suffers because only a few of the possible signals which might have been sent in the transmission channels B_1 through B_4 are ever produced. PCM, on the other hand, takes advantage of every possible signal which could be transmitted over the four channels.

Properties of PCM

The properties of PCM links are basically different from those of the analog types:

First, PCM signal-to-noise ratio is relatively independent of the carrier signal-to-noise ratio, so long as the carrier level is above the threshold level. A PCM system with a fixed code group can do little to improve its output signal-to-noise by increasing transmitter power once the carrier is above threshold.

Second, PCM methods are ideal for data transmission through repeaters, wherein the code elements are reshaped and retransmitted. The output of a binary PCM system may be applied directly to many automatic data reduction and storage systems, whereas analog systems require recording and later analog-to-digital conversion before being suitable for digital reduction.

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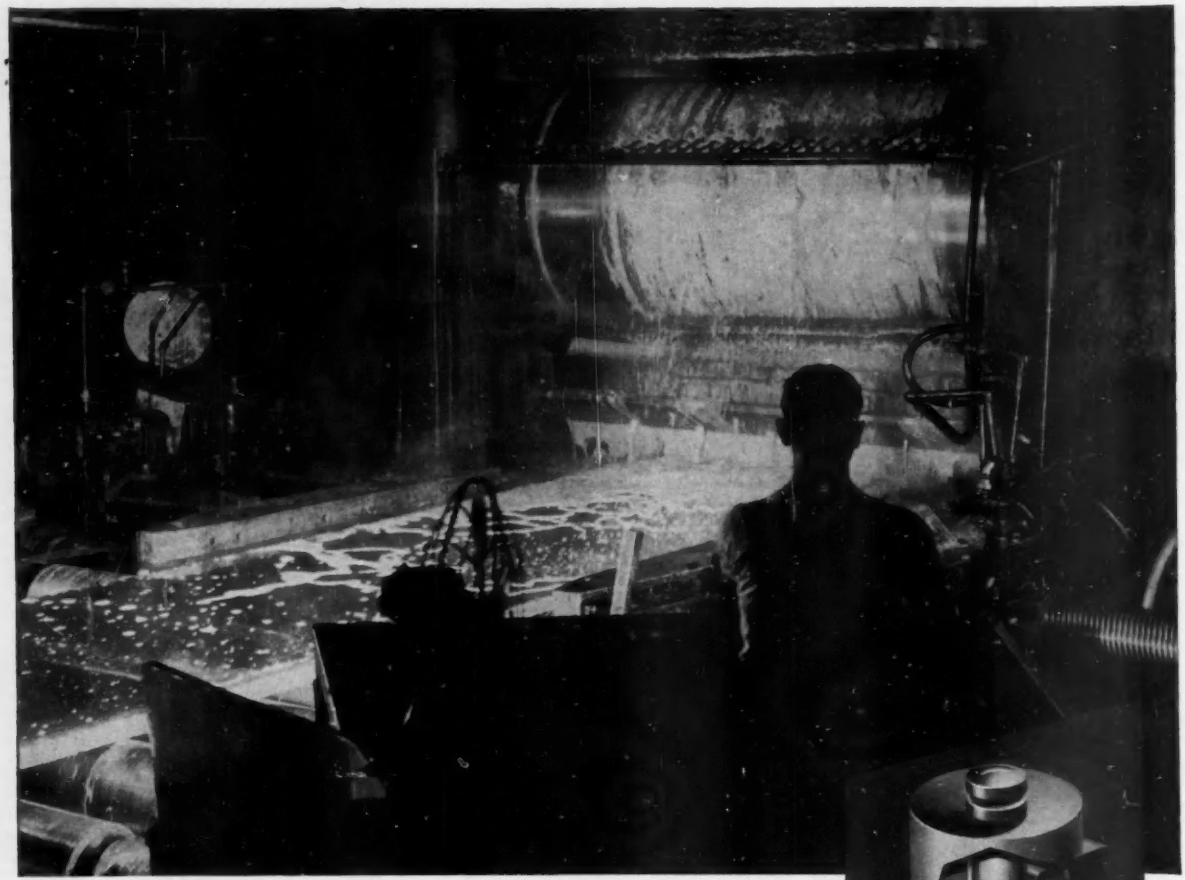

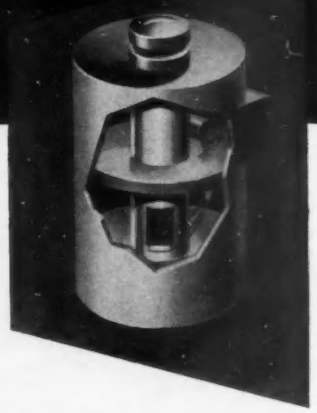

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Relay Memory Gets Cargoes Ashore

Digitizing techniques and relay storage provide a British shipping office with accurate indications of grab loads and the total weight lifted by dockside cranes in Essex.

P. A. JASSOY
Elliott Brothers (London), Ltd.

In a set of dockside cranes at Wm. Cory & Sons' wharf in Essex, electronic weighing with digital displays provides detailed information of each grab load and the total lifted. The system can be extended by radio link or landline to the head office.

A strain gage load cell in the standard electronic weighing systems mounts on the crane platform to measure the load in the grab through a floating pulley. This obviates extensible cables for the hook-mounted cell. Self-balancing servo indicators give a visual pointer indication of grab load; digital representation is obtained from a digitizer fitted to the pointer shaft. Translators and relay stores see to it that the grab load and the total appear on neon lamp displays.

Weight recording can be manual or automatic. If it is manual, the crane driver lifts the load, waits until the pointer tells him the load is steady, and then presses the record button. Both the grab load and total weight lifted appear on the display, and both remain visible until the next weighing operation or until erased by a second button. On automatic operation, the operator can give his whole attention to the crane, because sequencing circuits cut out the hoist motor when the load reaches a predetermined height. Weighing and recording take place during this 6-sec cut-out; control is then handed back to the driver, who discharges the load. Built-in inhibitors stop the crane when a preset total load has been lifted. This feature is particularly useful when a number of cranes are operating independently to unload a fixed amount of material from several holds of a ship. All cranes stop automatically when the required total has been discharged.

Figure 2 shows the block diagram of the digitizing system and relay stores. In returning to zero on the discharge of a load, the servo indicator trips a microswitch which clears all temporary stores and resets the sequencing relays. This prevents double recording of the one load. With a load in position the coded weight information is fed to the translator relays from an eight-bit disc. The input is in units of hundredweights (cwt)—which in avoirdupois measure is 112 lb (1/20 ton)—and in binary-coded cyclic decimal form. A simplified schematic of the relay matrix, Figure 3, shows the ten relays used for simultaneous conversion of the input to decimal form for visual display and to binary code for addition to the cumulated total.

The binary code output is stored in

FIG. 1. Automatic load recording fitted to the cranes at Purfleet wharf, Essex, makes possible accurate control of cargo discharge.

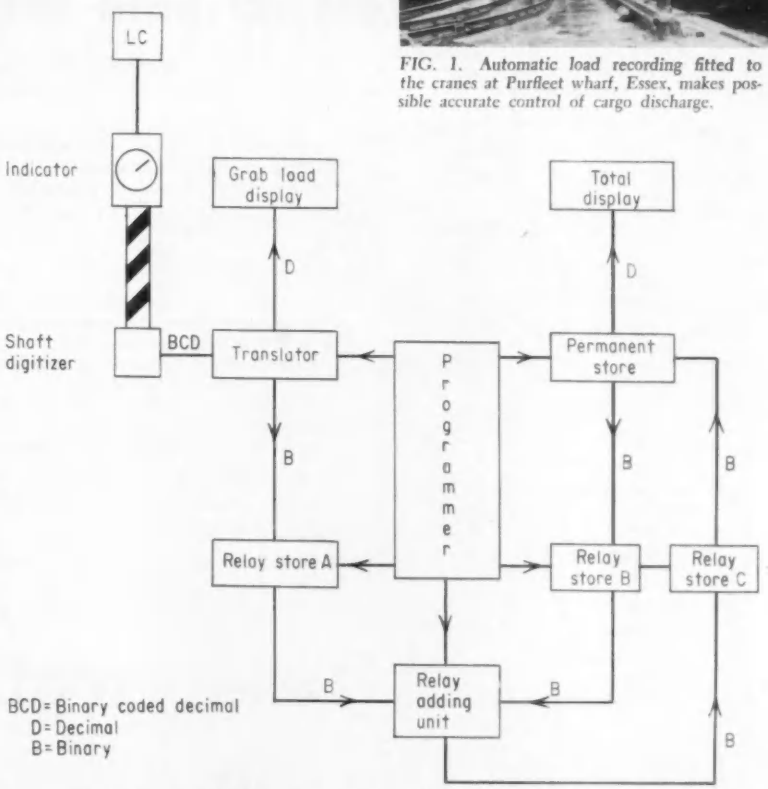
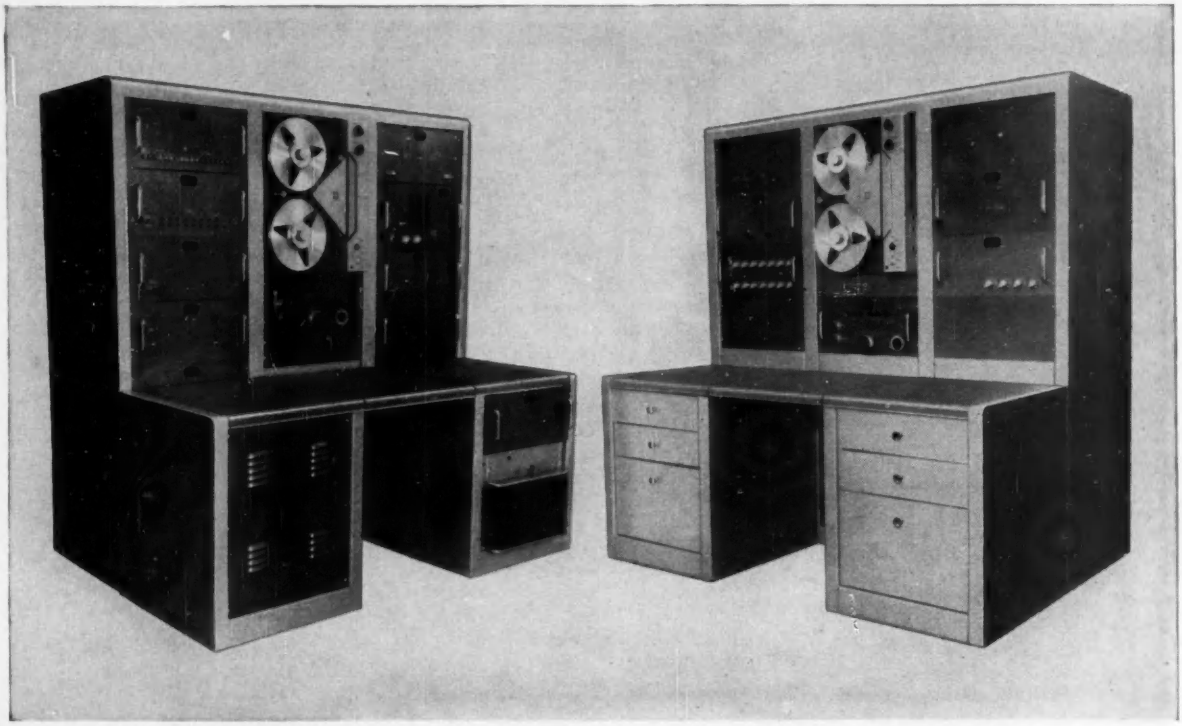


FIG. 2. The schematic shows method of obtaining cumulated total through relay stores.



This is the Honeywell 7000 digital data recorder-transcriber

. . . a high-speed electronic data acquisition and transcribing system for handling up to 100 channels of analog data with conversion to digital form for data processing.

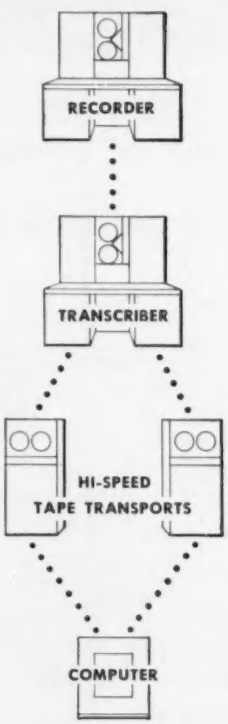
The Honeywell 7000 is a complete multi-channel, high-speed system consisting of two main units—the recorder and the transcriber. The first is located at or near the source of data and produces the first or intermediate tape. The transcriber is generally located at the computer and produces the final tape in the desired computer format.

The Honeywell 7000 is basically designed to perform these functions:

- **Accept input information from multiple transducers.**
- **Scan the input signals sequentially at high speed.**
- **Digitize each input in turn.**
- **Record the digitized values on magnetic tape.**
- **Reproduce the original tape.**
- **Select predetermined portions of the reproduced data.**
- **Rearrange the continuous data into suitable block form for computer input.**
- **Record these blocks of data on another tape for direct entry into the computer.**

The Honeywell 7000 is capable of a scanning rate of 10,000 samples per second. Variations of the basic system are available to adapt the system to meet differing application conditions.

Write for information on the Honeywell 7000 digital data recorder-transcriber . . . and application engineering assistance. MINNEAPOLIS-HONEYWELL, 10721 Hanna Street, Beltsville, Maryland.



The digital data recording-transcribing system* is manufactured by Honeywell under agreement with North American Aviation, Inc.

Honeywell

HONEYWELL *First in Controls*

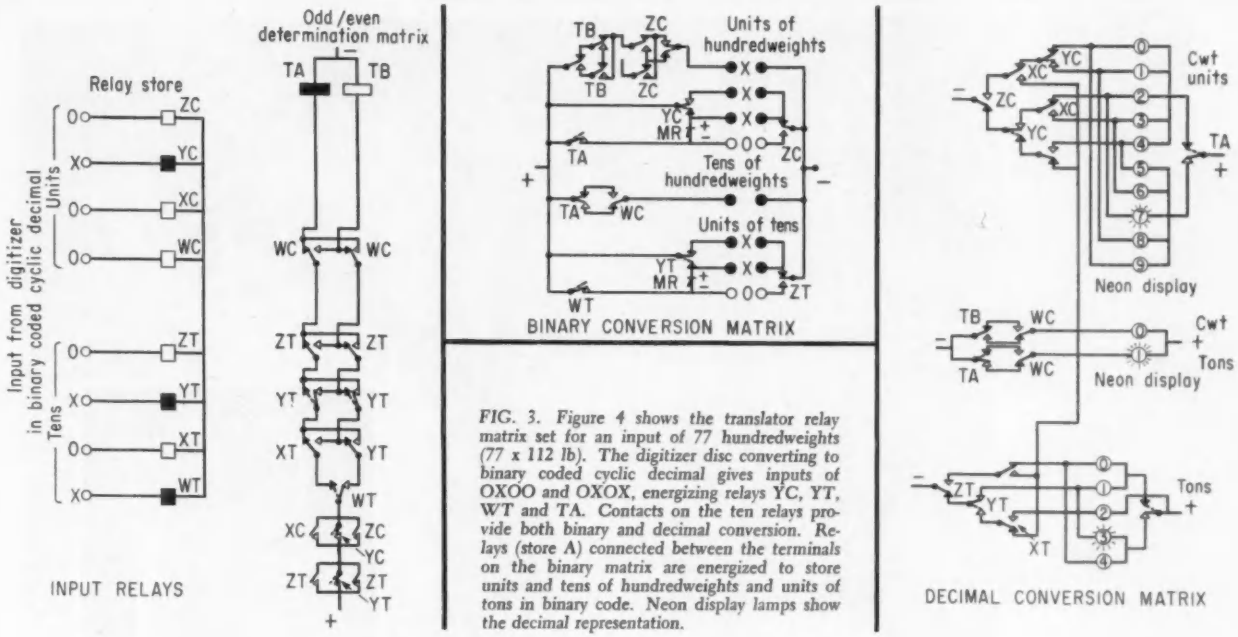


FIG. 3. Figure 4 shows the translator relay matrix set for an input of 77 hundredweights (77 x 112 lb). The digitizer disc converting to binary coded cyclic decimal gives inputs of OXOO and OXOX, energizing relays YC, YT, WT and TA. Contacts on the ten relays provide both binary and decimal conversion. Relays (store A) connected between the terminals on the binary matrix are energized to store units and tens of hundredweights and units of tons in binary code. Neon display lamps show the decimal representation.

relay store A while the programmer energizes and clears the permanent store, then passes to relay store B. The output contacts of both the A and B relay stores are connected to form adding circuits, and the sum of present load and the previous total is accumulated in the third store, C. The output contacts of this store then programs the permanent store uniselectors (stepping relays) to their new position and the information is converted to decimal form to illuminate the appropriate neon lamps in the total display. With the data stored as positional information on stepping relays, power failures leave the recorded total unaffected. Interlock circuits prevent the operator from clearing the totalizer to zero while the grab is loaded.

Computer Clips Balancing Time

This special-purpose analog computer locates turbine-wheel unbalance and tells how to correct it.

W. E. BOGGS, *Control Engineering*

When Tinius Olsen engineers tacked an analog computer onto a new balancing machine for General Electric, they speeded up turbine-wheel balancing 300 percent. Testing the heavy wheels in old cradle balancers had been slow and awkward. Now, testers measure unbalance in one place, correct for it in another. The special-purpose computer solves this problem by simply and quickly converting the unbalance data.

As a wheel spins on the bearings of the balancing machine (shown in Figure 1), velocity pickups measure vibration in the bearing planes. The signal from these pickups is calibrated to represent both the angle and amount of unbalance. Because the tester must make his corrections not in the bearing plane but at the surface of the wheel, he converts his data by dialing it into the computer, which shows him how many inch-

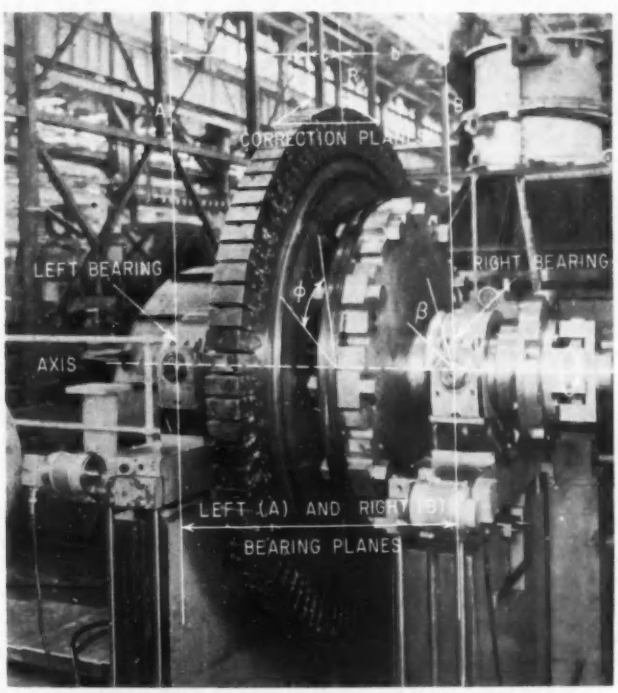
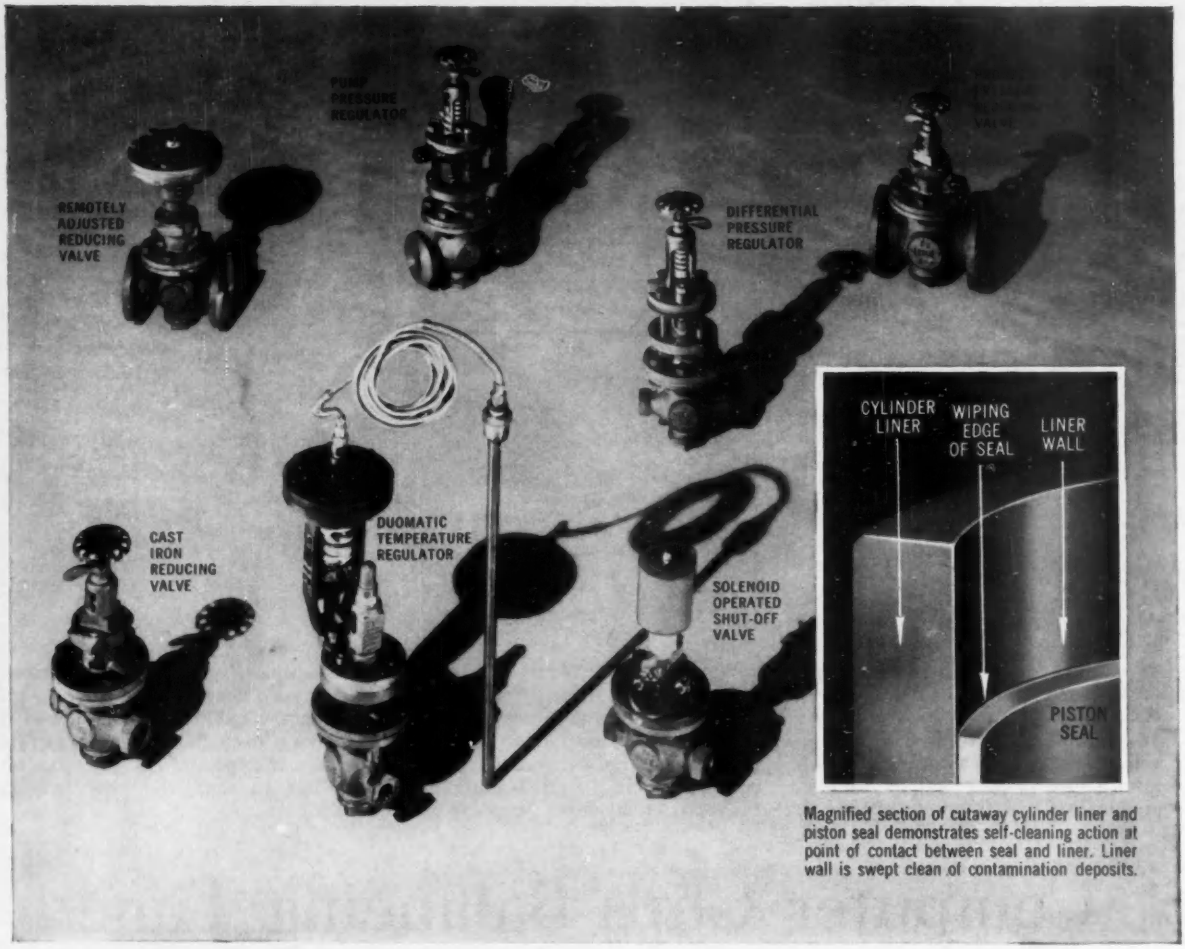


FIG. 1. Test wheel mounted on bearings of balancing machine. A and B are bearing planes, L and R correction planes. β is the angle of unbalance in plane B, α (not shown) the angle of unbalance in plane A. φ is the angle of unbalance in the correction plane.



Magnified section of cutaway cylinder liner and piston seal demonstrates self-cleaning action at point of contact between seal and liner. Liner wall is swept clean of contamination deposits.

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Bulletin 5307-A — Temperature Regulators

Or ask to see a demonstration model of the new pressure seal piston.

TRADE LESLIE MARK **REGULATORS and CONTROLLERS**

LESLIE CO., 211 Grant Avenue, Lyndhurst, New Jersey

grams to add in each correction plane.

The computer handles math that would give any tester headaches: for example, the sums of the axial moments in bearing planes A and B (Figure 1) are:

$$\Sigma M_A = aL + (a + c)\,R - (a + b + c)\,B = 0$$

$$\Sigma M_B = bR + (b + c)\,L - (a + b + c)\,A = 0$$

where A, B, L, and R are moments in their respective planes. From these equations are derived expressions for the unbalance in the correction planes L and R on the left and right surfaces:

$$R = \frac{1}{C}\,(bB - aA + cB)$$

$$L = \frac{1}{C}\,(-bB + aA + cA)$$

Solving for one plane at a time, as the computer does, the unbalance in each correction plane can be resolved into two vectors, at right angles to each other. The horizontal vector, K_1, in the left correction plane is

$$K_1 = \frac{1}{C}\,(-bB\cos\beta + aA\cos\alpha + cA\cos\alpha)$$

and the vertical vector, K_2, is

$$K_2 = \frac{1}{C}\,(-bB\sin\beta + aA\sin\alpha + cA\sin\alpha)$$

The angle of unbalance, ϕ, in the correction plane is represented by

$$\tan^{-1}\frac{K_2}{K_1}$$

and the magnitude of unbalance in the correction plane is the resultant of vectors K_1 and K_2, or

$$K = \sqrt{K_1^2 + K_2^2}$$

Computer inputs

Naturally, the tester doesn't have to go through this math to find out how big a slug of putty he needs to balance the left side of the wheel. To find the unbalance, the tester sets the following measurements manually on the computer dials:

- left and right distances: a and b in Figure 1—the distances from the bearing planes to the correction planes.
- center distance: c in Figure 1—the thickness of the wheel; litterally the distance between correction planes
- amount and angle of unbalance in both bearing planes: B at angle β in the right plane, A at angle α in the left plane

Figure 2 shows how the computer handles the problem: potentiometers in the computer circuits represent the input data—angular data on sine-cosine pots, amount and distance data on linear pots. Summing amplifiers combine the resistance products representing vertical and horizontal unbalance vectors K_1 and K_2, and feed them as inputs to the stator windings of a resolver; a servo system positions the resolver's rotor windings. One rotor-winding output, K_c, detours through a dividing amplifier to show up as a voltmeter reading of K, the amount of unbalance at the wheel's left surface. The output from the other rotor windings feeds back to the servo system and produces a shaft rotation representing ϕ, the angle of unbalance in the correction plane. This shaft rotation shows up as a dial readout.

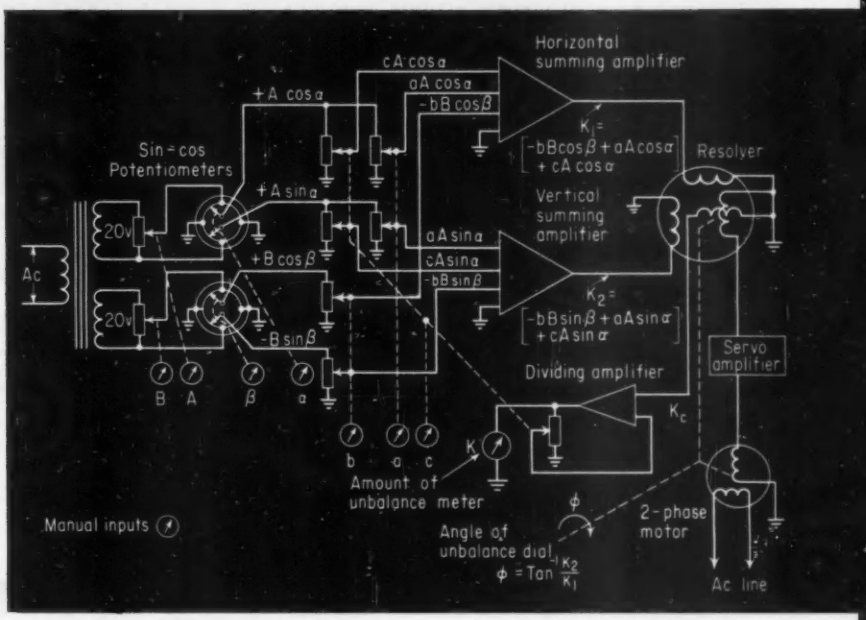


FIG. 2. Block diagram of computer circuits. K represents the amount of unbalance in the left correction plane, ϕ its angular location. A and B represent amounts of unbalance in the left and right bearing planes; a, b, and c are distances. All computer inputs are manual.

Testing machine operation

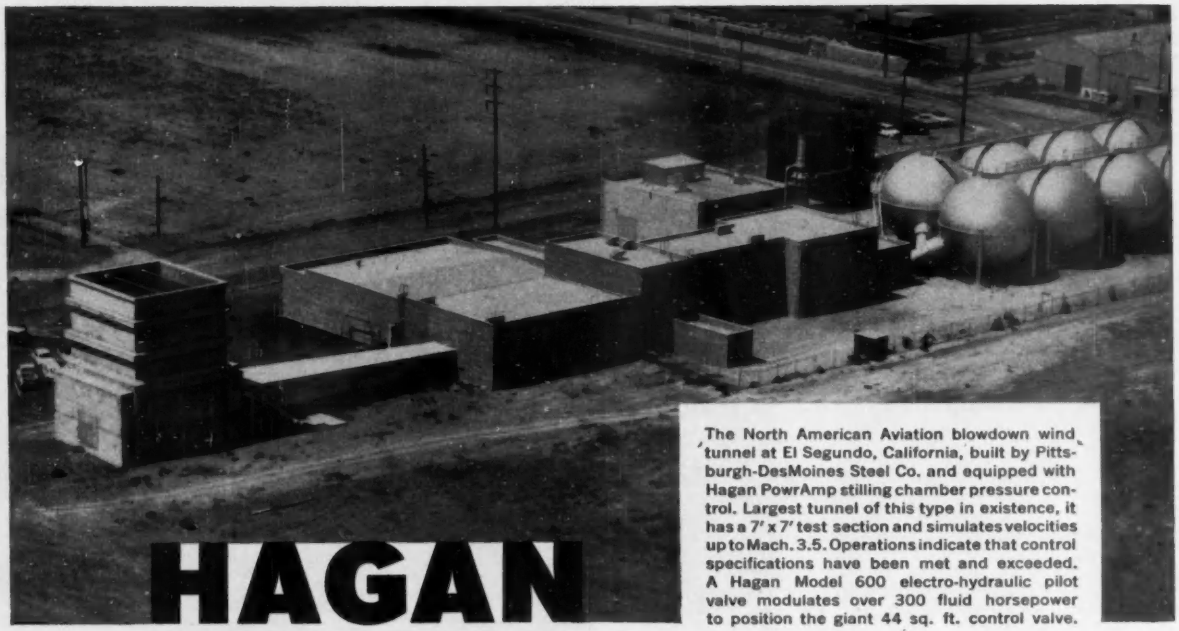
Of all the components of computer input, only the distances (left, center, and right) must be measured by the operator; the angle and amount of unbalance at the bearings are measured by the balancing machine.

Magnitude of unbalance is measured by squaring off a sine-wave signal from the vibrating bearing. The squared-off wave is differentiated to form a pulse which is compared to a reference pulse generated by the rotating driveshaft. The two pulses gate a multivibrator: the reference pulse opens the gate, the bearing pulse closes it. The average plate current in the multivibrator is proportional to the magnitude of the turbine wheel's unbalance in the bearing plane, and shows up on a voltmeter.

The test machine also measures angle of unbalance automatically. Like magnitude, angle of unbalance is measured with squared-off sine waves differentiated to pulse form. They feed one grid of a flip-flop; the other grid receives a pulse from the rotating driveshaft. The phase difference of the pulses to the grid equals the angle of unbalance of the test wheel. A voltmeter integrates the current on a scale calibrated in degrees to get a reading of the angle of turbine-wheel unbalance in the bearing plane.

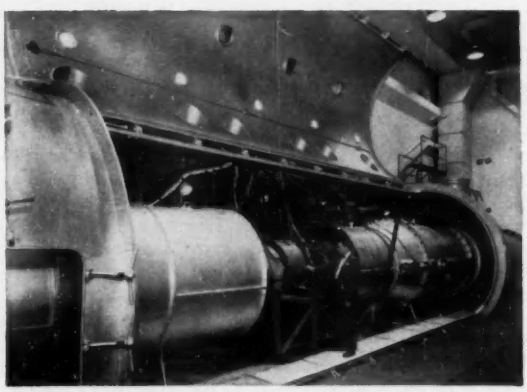
With these measurements made for him, the tester has only to add his own setup measurements of distances to complete computer input. The voltmeter connected across the computer's resolver shows the unbalance to be corrected at the turbine wheel's surface, and a dial rotation indicates the angular location of the unbalance.

The computer's inputs are all mechanical, but there is no reason why they have to be. Analog information, in the form of pulse unbalance and sine-wave input, could be fed directly to the computer; and with a few more pieces of hardware, the computer could control a completely closed-loop testing cycle.



The North American Aviation blowdown wind tunnel at El Segundo, California, built by Pittsburgh-DesMoines Steel Co. and equipped with Hagan PowrAmp stilling chamber pressure control. Largest tunnel of this type in existence, it has a 7′ x 7′ test section and simulates velocities up to Mach. 3.5. Operations indicate that control specifications have been met and exceeded. A Hagan Model 600 electro-hydraulic pilot valve modulates over 300 fluid horsepower to position the giant 44 sq. ft. control valve.

HAGAN CONTROLS keep pace with the Missile Age



Engine altitude test chamber at Pratt & Whitney's Wilgoos Laboratory simulates flight conditions at high altitudes. The many giant exhausters and compressors which produce these conditions are protected by Hagan automatic surge control systems utilizing Hagan pressure-ratio computers. In addition, engine inlet conditions simulating high speed flight are maintained automatically with a Hagan PowrAmp pressure control system.

Hagan's PowrAmp control components and systems are in successful operation on wind tunnels, including many blowdown tunnels, on engine test cells and missile component test cells. Hagan controls have been selected for these critical installations because of their ability to handle heavy duty tasks with laboratory accuracy.

The PowrAmp line includes transducers for most key variables, electronic control computers and pneumatic, hydraulic and electro-hydraulic operators and pilot valves. All of these are high precision devices which are designed for fast, accurate operation. They are rugged and powerful; the electro-hydraulic pilot valves, for instance, will handle up to 300 usable hydraulic horsepower.

Write for Bulletin MSP-133, which describes the complete PowrAmp line in detail.

From this control room at Wyle Laboratories component test facility in Los Angeles, Hagan controls produce programmed missile fuel flow simulations to test rocket engine components for America's mightiest missiles.

These installations represent only a few of the hundreds of successful Hagan installations in wind tunnels, engine test cells and aircraft and missile test facilities.

HAGAN CHEMICALS & CONTROLS, INC.

HAGAN BUILDING, PITTSBURGH 30, PENNSYLVANIA
DIVISIONS: CALGON COMPANY, HALL LABORATORIES
IN CANADA: HAGAN CORPORATION (CANADA) LIMITED, TORONTO

A Logic Circuit That Tells Correct Controller Action

RICK A. DENNING
U. S. Army Corps of Engineers

Basically, a cascade control (Ref. 1) is a multiple-loop control system. The process illustrated in Figures 1 and 2 is a three-loop pressure control. The primary loop is closed by the feedback of the master or controlled variable while the secondary loops are closed by feedback of the secondary variables, which influence the value of the master variable. Thus, a cascade control is a control combination wherein the master variable is held to closer limits by having the output of the master controller adjust the setpoint of the secondary controller.

Cascade controls are becoming more and more commonplace, so that there is an increasing need for a better way to solve the problem of determining whether the individual control elements in the various loops should be direct- or reverse-acting.

A direct-acting pneumatic controller, pneumatic set mechanism or transmitter of a measured process variable is one whose output increases as its input signal increases. The output of a reverse-acting device decreases as its input increases.

One way to solve these problems is to use charts (Ref. 2) containing all the logical combinations of choices. An electrical circuit is proposed here which can be expanded to include any number of closed loops and reverse-acting measuring elements. Figure 3 is a circuit which will solve for the required action of each of the controllers, measured-variable transmitters, and pneumatic set mechanisms in any two- or three-loop cascade control system.

Using the circuit

In the circuit of Figure 3, a switch is used for each element for which a direct or reverse action is possible. For rapid selection the switches should be used in the order in which the actions occur in the physical system. All switches for which the corresponding control elements do not exist must be thrown to the "direct" position.

The lights may indicate that the final control element is "open", "on", etc., when they are lighted or the reverse. The choice is decided automatically by the required condition for the master variable, as its lamp is always on. Other lights follow suit.

Direct or reverse?

The correct actions for the elements in the three-loop pressure control system of Figures 1 and 2 depend on the required valve actions; suppose these required actions are:

Increase in pressure closes valve
Air failure at pressure transmitter closes valve
Air failure at pressure controller closes valve
Increase in outflow (intermediate secondary) opens valve
Air failure at outflow transmitter opens valve
Air failure at outflow controller closes valve
Increase in inflow (final secondary) closes valve
Air failure at inflow transmitter opens valve
Air failure at inflow controller closes valve

The correct actions would then be indicated by the lamps being on or off. In the order shown in Figure 3, the lamps should be: on/on-on/off-off-on/on-off-on. The required actions for each of the elements to obtain this result is indicated by the position of the switches: reverse-direct/reverse-reverse-reverse/reverse-direct-reverse.

To check this result refer to Figure 2. The sign of the transfer function of each block is shown, positive for direct action, negative for reverse. The feed-forward signal is subtracted from

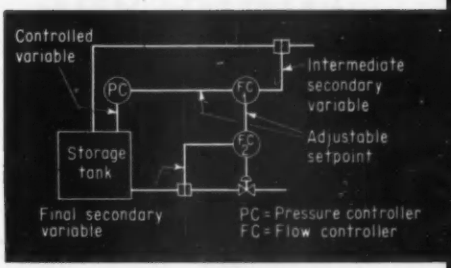


FIG. 1. Typical three-loop cascade control system, measured variable transmitters omitted.

FIG. 2. Block diagram of system of Figure 1 for operating conditions stated in text.

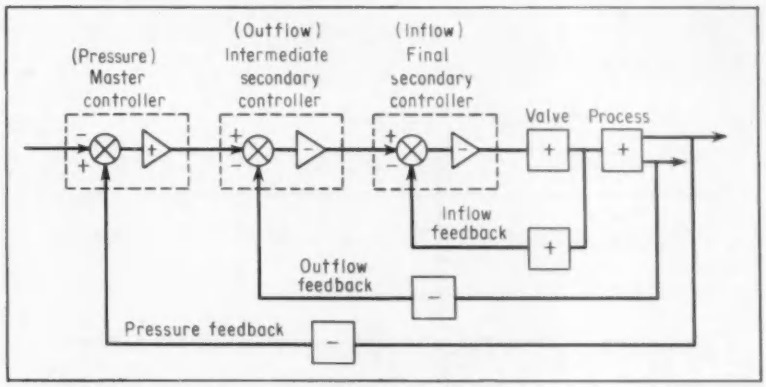
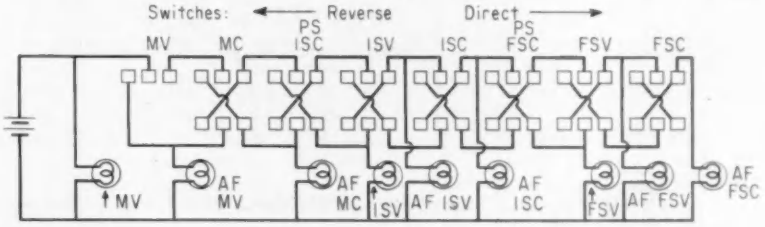


FIG. 3. Circuit will solve any two- or three-loop cascade system. There is a switch for each element which can invert signal. Lights indicate condition of final control element.



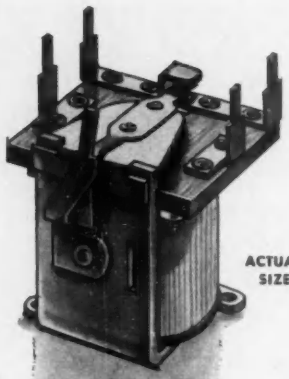
MV - Master Variable Transmitter
MC - Master Controller
IMV - Increase in Master Variable
AFMV - Air Failure at Master Variable Transmitter
AFMC - Air Failure at Master Controller
IS - Intermediate Secondary
FS - Final Secondary
PS - Pneumatic Set Mechanism

RBM

TYPE MS

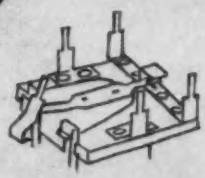
MINIATURE SENSITIVE RELAY

Millions of Type MS relays now in extensive use in highly competitive markets—automotive, radio, and television. Proven ideal for applications requiring a sensitive, highly reliable single pole or common muitiple contact DC unit. Mass production, and RBM's experience in assembly techniques, make Type MS your *low cost* solution for volume usage.

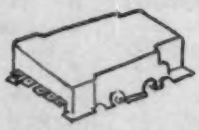


ACTUAL SIZE

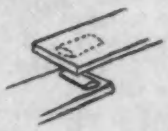
BUILT TO WITHSTAND EXTREME ENVIRONMENTAL CONDITIONS AT **LOW COST**



AVAILABLE WITH PRINTED CIRCUIT TERMINALS



ENCLOSED CONTACTS WHERE DESIRABLE



X-BAR CONTACTS INSURE MAXIMUM RELIABILITY

NO CURRENT-CARRYING RIVETS

COIL CONSTRUCTION MEETS UNUSUAL CLIMATIC CONDITIONS

CHARACTERISTICS

	MS-40	MS-25
COIL RESISTANCE	TO 10,000 OHMS	TO 15,000 OHMS
MAX. COIL POWER	1 WATT	1.5 WATT
MIN. COIL POWER	.40 WATT (SINGLE POLE)	.025 WATT (SINGLE POLE)
CONTACT RATING	1 AMP. 28V D.C. OR 115V A.C. (NON-INDUCTIVE)	1 AMP. 28V D.C. OR 115V A.C. (NON-INDUCTIVE)

CONTACT FORMS

SINGLE POLE	COMMON MAKE
NO	3 NO & 1 DT
NC	5 NO
DT	

TERMINALS

(A) SOLDER TYPE - ALL VERSIONS

(B) PRINTED CIRCUIT TYPE (SINGLE POLE VERSIONS ONLY)

Consult your local RBM Product Application Engineer or write for Bulletin MS-3

RBM Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA

the feedback signal by a direct-acting pneumatic set device while the feedback is subtracted from the feed-forward in the reverse-acting pneumatic set device. These devices are represented by error detectors in the block diagram. For this example the required valve is an air-to-open spring closing type; an increasing input signal opens the valve and gives increased flow; therefore the valve is shown as direct-acting. An air-to-close spring opening type would be considered reverse-acting and given a negative sign (caution: valve manufacturers base their definition of direct-acting on the direction of valve stem travel rather than on change in controller flow; thus an air-to-open spring closing valve could be made either direct or reverse-acting simply by reversing valve seat and stem).

Tracing the signal, as the pressure increases, the output of the pressure transmitter decreases (plus × minus = minus). It also decreases for air-failure at this transmitter, as desired. The output of the first error device decreases. This makes the feed-forward signal to the second error device decrease and the output error decreases. Similarly, a decrease in outflow is inverted by its transmitter to an increase in feedback signal, decreasing the output error; air failure at this transmitter would decrease the feedback, causing the opposite action, as required. The signal to the third error device, after inversion by the intermediate secondary controller, increases and the output error increases. Similarly, a decreased inflow decreases the feedback signal and the output error increases —air failure at this transmitter decreases the feedback, as required. The signal to the valve, after inversion by the controller, closes the valve.

REFERENCES

1. *CASCADE CONTROL SYSTEMS*, Norman W. Gollin, "Control Engineering", July 1956, pp. 94-98.
2. *DIRECT OR REVERSE CONTROLLER ACTIONS*, George Platt, "Control Engineering", May 1956, pp. 63-65.

Data Logging Locates Lost Buses

A system devised by the London Transport Authority splits each bus route into sections with a number of check points. At each of these the identification number of each bus is read as it passes and is transmitted over telephone lines to the central office. Here the number is displayed on a panel appropriate to that section of the route and also recorded on a chart. When each bus passes the next check point the number is transferred from one display panel to another, so that each panel indicates the identification numbers of buses between the two boundary check points.

Normally mounted with a 7-digit timing plate above a 3-digit code plate, glass reflectors act as efficient light sources to identify London's buses to photoelectric readers at automatic check points.

The largest item numerically in the system is the bus-mounted equipment required for each of London's 7,000 buses. This has to be designed as economically as possible. Other important factors to be considered are:

- the equipment must allow for rapid and easy changes of identification numbers
- the roadside equipment must be easily installed and maintained
- the system must operate by day and night over a range of bus speeds from one to 30 miles per hour.

The scheme installed for pilot operation on one of the north-south routes traversing the center of London uses a pair of reflecting plates mounted on each bus. Each bus identification number is reproduced in binary code on the plate by a $\frac{3}{8}$ in.-diameter glass reflector for each digit and a corresponding blank for each zero. These reflectors are similar to those used as road "cat's eyes" and have a very narrow reflecting field and negligible scatter. The plates are mounted in clips on the side of the bus above the driver's cab, see cut.

Several problems had to be solved in the design of the reflecting system: variation in height of the reflectors due to loading conditions of the 56-passenger bus, variation in angle of the reflectors due to road camber, and provision of adequate reflection over the speed range.

The loading and angular variation problems are solved simultaneously by mounting two rows of reflectors on each plate, one inch apart. To compensate for varying speeds two sets of plates separated by 10 in. are used on each bus. The upper plate provides a series of timing impulses from a complete row of seven reflectors with one used for a clear down signal. The lower plate contains the binary coded identification of the bus. By the use of coincidence circuits combining the signal from both the timing and the identification plate and with a 2-in. horizontal distance between each individual reflectors, adequate signals are received up to speeds of 40 mph.

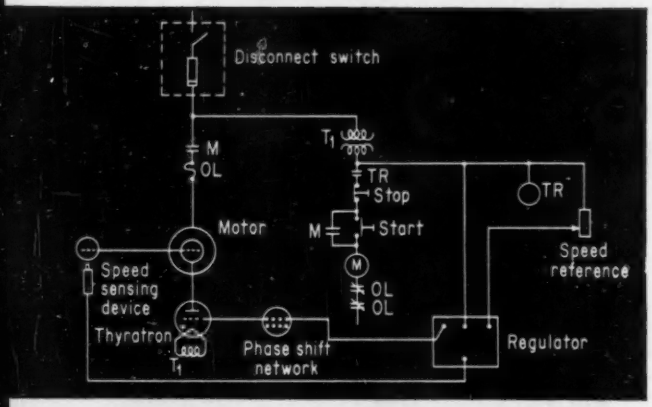
Roadside scanning equipment consists of a modulated light source focused onto the bus plates at each check point. A serrated rotating disc provides a 3,000 cps modulated light beam which is split by two mirrors set at right angles. Additional plane mirror reflectors project the two beams at the correct separation to strike the bus plates. The reflected light from the plates is focused on two phototransistors in the scanner unit. The resultant coded signal is then passed to a pair of resonant amplifiers which reject all extraneous signals not part of the bus identification signal.

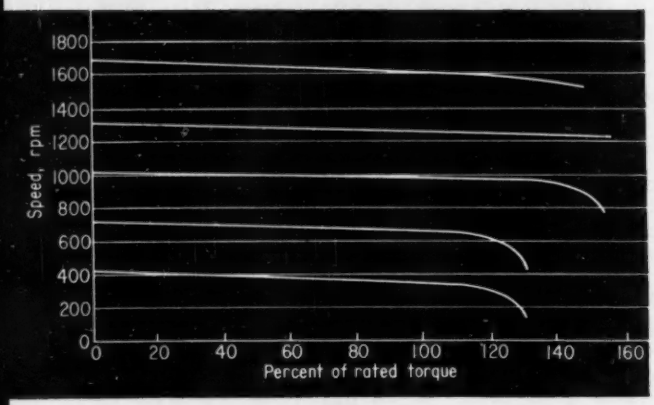
The display arrangements at a center consist of a series of panels, one for each scanner position. The passage of each bus from one check point to another is traced by the illumination of its appropriate lamp on one panel after another. A chart records bus density and running order.

NEW PRODUCTS

LISTING IN GROUPS

Designs of the Month
Data Handling & Display
Primary Elements & Transducers
Controllers, Switches & Relays
Power Supplies
Actuators & Final Control Elements
Research, Test & Development
Component Parts
Accessories & Materials





NEW DRIVE offers ac speed control.

The simplified circuit diagram shown here represents the basic control scheme for an unusually versatile, adjustable-speed ac drive. In this basic circuit, a thyratron tube controls the secondary current, hence torque and speed, of a wound-rotor induction motor. When the motor primary is energized and the speed reference setting exceeds the actual motor speed, the regulator, through a phase shift network, allows the thyratron to conduct through the motor secondary. This current produces a field which reacts with the field of the motor primary to produce an accelerating torque. As the speed approaches the reference setting, the regulator reduces tube current until, at the desired speed, torque is just sufficient to carry the load.

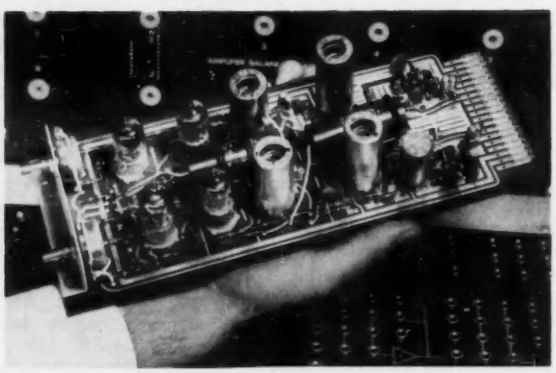
Features that may be added to this basic circuit include reversing, jogging, threading, current limiting, braking, etc. Manufacturer offers several methods of speed sensing and indicating, as well as several methods of regulating and control.

Units can be designed to satisfy one or more of the following requirements: slow-speed starting, smooth acceleration, gradual stopping, synchronization, and automatic control. Power outputs range from 1 to 50 hp with maximum speeds of 3,400, 1,700, or 1,130 rpm. Standard drives operate on 208/220/440 or 550 volts, three-phase, 60 cps. Special two-phase or 50-cycle drives can also be furnished.

Curves at the left show a sample set of regulation data on a 5-hp drive with current limit. Note how the current limit feature causes a pronounced speed drop at excessive overloads and low speeds, where ventilation becomes a problem.–The Electric Products Co., Cleveland, O.

Circle No. 1 on reply card

DESKTOP COMPUTER costs $2,285.



Item in hand is a dual, plug-in type, chopper-stabilized amplifier; five of these are used in the new Model 3400 analog computer. The computer, complete with amplifiers, built-in null voltmeter, cyclic reset generator, power supplies, and problem board sells for $2,285.

Features of the Model 3400 include: positive and negative reference voltage, removable problem board, individual overload indicators, and amplifier balance controls. Power requirements are 250 watts from a 115/230-volt, 50-60 cps, single-phase supply. Each of the 10 amplifiers features a dc gain of more than 50 million. Overall dimensions of the computer with problem board are 21 in. wide by 19 in. high by 29 in. deep. Shipping weight is approximately 125 lb.–Donner Scientific Co., Concord, Calif.

Circle No. 2 on reply card

CONTROL AMPLIFIER offers high linearity.

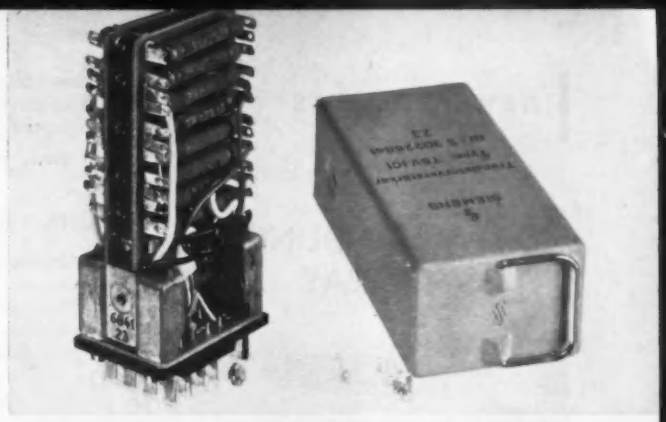
Photo right shows a new two-stage transistorized amplifier, specifically designed for control applications. Simple alteration of its input and output connections provide a wide variety of amplifier functions.

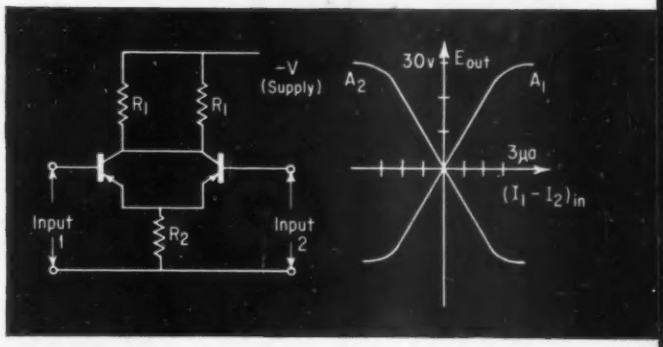
The circuit diagram below the photo illustrates a typical application. It shows one stage of the amplifier connected as an emitter-coupled push-pull circuit. The second stage would be similarly connected. The circuit reacts only to differences in the input signals. This not only leads to a high static accuracy, but makes the amplifier relatively insensitive to changes in input drive, supply voltage, and temperature. Thus the amplifier will still function with only 10 percent of its normal supply voltage, and the input current changes by only 0.5 μa per deg C.

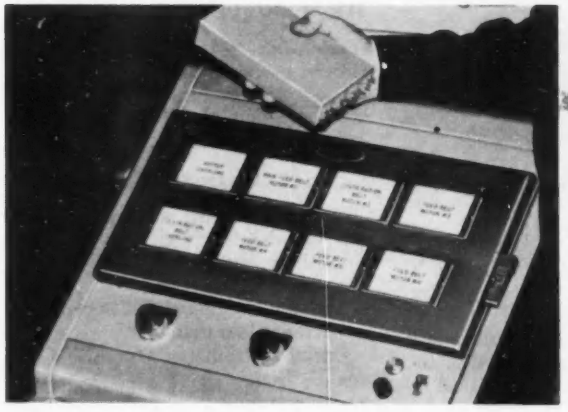
The curves to the right of the circuit diagram describe the static transfer characteristic of the amplifier. Transfer impedance (i.e., output voltage divided by the differential input current) is in the order of 10 megohms, and output impedance is 20 k. Various circuit connections provide input resistances between 2 and 4 k.

Another feature worth noting is that when the amplifier is fed with a symmetrical input, capacitive coupling to the two input terminals is effectively canceled. This eliminates the need for shielded inputs.—Siemans-Schuckertwerke AG, Erlangen, West Germany.

Circle No. 3 on reply card



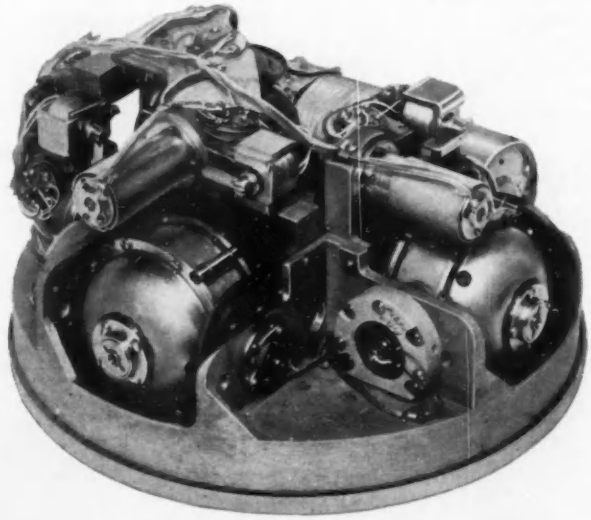




ANNUNCIATOR uses static switches.

A new type of annunciator for monitoring complex systems uses static-magnetic controls instead of precision relays to provide a high degree of reliability in monitoring critical operations or conditions. Plug-in design of the elements permits rapid sequence changes without rewiring and facilitates expansion. In addition to the ordinary logic functions, a "retentive" memory circuit is available. In the event of a power failure, this circuit "remembers" its previous state after power has been restored. The static-magnetic annunciator is particularly applicable to industrial systems involving interlock or automatic shutdown.—Panellit, Inc., Skokie, Ill.

Circle No. 4 on reply card



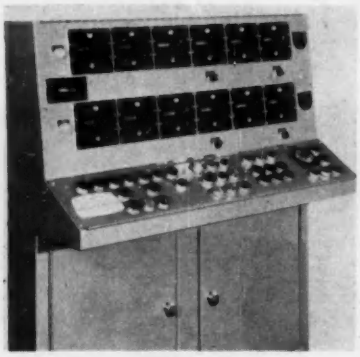
GYRO TRANSDUCER gives three-axis data.

This highly accurate gyro transducer consists of three gyros mounted so as to sense motion about the roll, yaw, and pitch axes. It thus provides an accurate reference in the form of an electrical signal proportional to displacement about the outer gimbal axis.

Hermetically sealed, the unit weighs 19¼ lb, including caging mechanisms, inverter, and radio-noise filters. Gyro motors operate directly from a 115-volt, 400-cps source. If necessary, the unit can be supplied with 27 vdc, and the 400-cps power can be generated internally. Normal altitude and humidity conditions have no effect on the transducer, which will perform satisfactorily at temperatures from minus 65 to plus 160 deg F. Applications include aircraft controls and telemetry systems.—Clary Dynamics, San Gabriel, Calif.

Circle No. 5 on reply card

DATA HANDLING & DISPLAY



BATCH CONTROL

Shown is the control panel for a new remote batching system, which consists of one or more suspension hopper scales connected to the panel at a remote location. Formulas are set up on the board. A "batch quantity" selector permits the operator to change the batch size without resetting the weights of individual ingredients. Operating principle involves balanced potentiometer bridges.—Toledo Scale Corp., Toledo, O.

Circle No. 6 on reply card

LOW-COST SCOPE

The Model P-1 Panelscope, above, consists of a cathode ray tube with a usable screen area of 1¾ by 3 in., a high-voltage power supply, positioning, beam, and focus controls, and an edge-lighted graph screen with filter. Unit requires just 5¼ by 5⅜ in. of panel space, and a depth of 10 in. It weighs less than 5 lb and draws less than 10 watts of line power. Price is $80. An indicator model, with built-in rectified low voltage supply, costs $20 more.—Waterman Products Co., Inc., Philadelphia, Pa.

Circle No. 7 on reply card

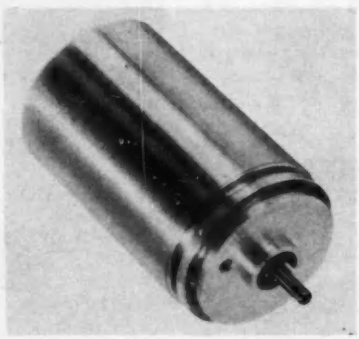
RECORDING METERS

A new automatic recording meter provides continuous automatic logging at low cost. Four of these compact units fit on a standard 19-in. relay rack panel. A pressure-sensitive paper eliminates the problems of ink recordings. Unit price is $69.50.

Characteristics:

Full-scale accuracy: within 2 percent
Full-scale sensitivity: 1 ma dc
Chart speeds: 1 to 30 in. per hour
Maximum chart time: 31 days
Coil resistance: 100 ohms, plus or minus 1 percent, critically damped
—Rust Industrial Co., Inc., Manchester, N. H.

Circle No. 8 on reply card



A STEP AT A TIME

Pictured is a new precision incremental motor suitable for remote positioning applications. Designed to rotate an external shaft and connected load through any angle up to 36 deg, the motor operates on pulsed electrical input signals.

Characteristics:

Pulse rate, max: 30 per sec
Load inertia: 0 to 25 gm cm²
Load torque: 0 to 2 oz-in.
Input voltage: 28 vdc
Power: 15 watts at 50 percent duty cycle
Rotation: cw or ccw
—Clary Dynamics, San Gabriel, Calif.

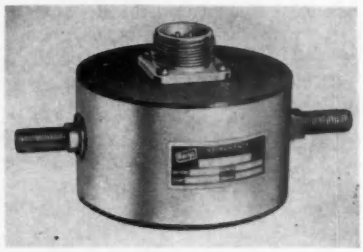
Circle No. 9 on reply card

PLUS.....

(10) Package units for two-motion **numerical positioning control** are now available from **General Electric Co.**, Schenectady, N. Y. . . . (11) The **Datex Div. of G. M. Giannini & Co.**, Monrovia, Calif. announced production of a **linear encoder system** for measuring and recording lengths from 0 to 100 ft. . . . (12) Developed by the **Digitran Co.**, Pasadena, Calif., a new line of three- and five-**decade switches** features digital indication of switch position. . . . (13) A two-channel direct-writing **oscillograph** offered by **Brush Instruments,** Cleveland, O., features chart speeds up to 1,250 mm per sec.

Circle No. 10, 11, 12 or 13 on reply card

PRIMARY ELEMENTS & TRANSDUCERS



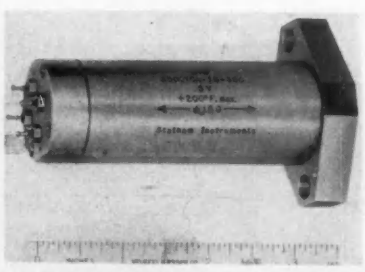
HIGH OUTPUT

The Model 9-1 force transducer, a differential transformer type, features an output of 1.68 volts, full-scale, with an input of 115 vac to a 5,000-ohm resistive load.

Characteristics:

Temperature drift: within 2 percent per 100 deg F
Sensitivity: within 2 percent, full-scale
Capacities: 75 or 240 lb
Maximum nonlinearity: 0.5 percent
Hysteresis: less than 0.09 percent
—Edcliff Instruments, Monrovia, Calif.

Circle No. 14 on reply card



WIDE FREQUENCY BAND

Use of gas damping in the Model A501 unbonded strain gage accelerometer permits operation over a wide temperature range without the addition of a heater jacket. Maker says

HOW TMI KEEPS THE FINGER OF TECHNOLOGY ON YOUR MAGNETIC CORES...

EVERY STEP OF THE WAY !

Magnetic core making is a fine art at Telemeter Magnetics, Inc., where the most experienced technologists in the field follow the production of your cores every step of the way: from specification for your individual application...through the most painstaking precision methods of manufacture, testing, and quality control...to consistently dependable delivery, right on time. Facilities are the finest and most complete in the entire ferrite storage industry; for example, there's the uncanny precision equipment that grades 18,000 cores per hour. Pioneers in the development of magnetic cores from the beginning, TMI today is the nation's headquarters for everything in magnetic storage, including complete assemblies and installations. Why not do as the world's biggest core users do...call on this wealth of technological know-how for all your core needs, as well as the answers to special application problems. *Write for company brochure.* Dept. CE 6.

0/1 **TELEMETER MAGNETICS** *Inc.*

2245 Pontius Avenue, Los Angeles 64, California / Manufacturers of cores, matrices, memory units, data translators, and custom-engineered data handling systems.

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General Purpose Relays

MEASURE ONLY:
1½" x 1½" x 1⅛"

BUT CARRY:
to 25 A. resistive at 115-230 V., A. C.; 1 h.p., 125 V., 2 h.p., 250 V., A.C.; D. C. and other higher ratings on request.

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MOUNTINGS:
Socket, panel and sidewall arrangements standard; others to meet special needs.

"Diamond H" engineers are prepared to work out variations of these rugged, dependable relays to meet your specific requirements in such applications as **automation controls, appliances and air conditioning equipment,** or what you will. Just ask.

THE
HART
MANUFACTURING COMPANY
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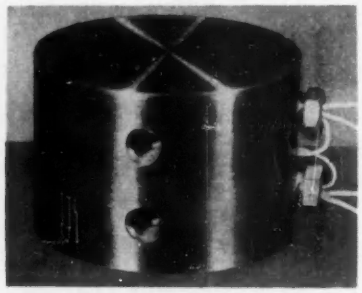
Hartford, Conn.
Phone Jackson 5-3491

NEW PRODUCTS

that at room temperature the instrument has a useful frequency band which is twice as wide as that of a standard accelerometer. Range is from plus or minus 5 to plus or minus 50 g's. Applications include missile and aircraft flight instrumentation.–Statham Instruments, Inc., Los Angeles, Calif.

Circle No. 15 on reply card



USES THERMISTORS

Designed for vapor-phase chromatography, this new conductivity cell uses thermistors as sensory elements. Available in two sensitivity ranges, it can be used in new or existing chromatographic apparatus. Features include a small internal volume, fast response, and convenient mounting. Stainless steel enclosure has leak-free connections. Cells require 7.5 or 12 vdc at 3 to 22 ma.–Largent Co., Houston, Tex.

Circle No. 16 on reply card

VELOCITY METER

Pictured is the Inertial Velocimeter, an integrating accelerometer that reacts to acceleration forces and yields an output signal which is the time integral of that acceleration. It measures 1½ in. in diam by 3½ in. overall, and weighs less than 1 lb. Power requirements may be as low as 2 watts from a 26-volt, 400-cycle, single-phase supply.–Instrument Development Laboratories, Inc., Attleboro, Mass.

Circle No. 17 on reply card

SILICON RESISTOR

Called the Sensistor, a new solid-state temperature sensing silicon resistor boasts a positive temperature coefficient of resistance of 0.7 percent per deg C. It should find wide application as a temperature compensating device in miniaturized amplifiers, servos, computer switching circuits, and power supplies.

Characteristics:

Types: Two, molded or welded case
Wattage: ⅛ or ¼ watt
Resistance tolerance: 10 percent
Full-load temp: 100 or 150 deg C
Resistance ratings: 100 to 1,000 ohms
–Texas Instruments Inc., Dallas, Tex.

Circle No. 18 on reply card

PLUS.....

(19) Three lightweight **vibration pickups** for monitoring jet engines and other equipment have been added to the product line of **Consolidated Electrodynamics Corp.,** Pasadena, Calif. . . . (20) **Sanders Associates, Inc.,** Nashua, N. H., have developed a new **rate gyro** that provides constant damping. . . . (21) A **liquid level sensor,** using beta radiation, is now available from **Robertshaw-Fulton Controls Co.,** Anaheim, Calif. . . . (22) **Fischer & Porter Co.,** Hatboro, Pa., calls its new **indicating flowmeter** the Mighty-I.

Circle No. 19, 20, 21 or 22 on reply card

CONTROLLERS, SWITCHES & RELAYS

RUGGED CONTROLS

Two new magnetic amplifier systems possess extreme shock and vibration resistance. Power requirements at standby and during operation are said to be negligible. Possible uses include on-off, proportioning, or pulse-

Chalmer E. Jones discusses DIGITAL COMPUTERS IN POWER PLANTS

Daystrom Systems has designed and shipped the first general-purpose digital computer to be applied "on line" for data handling and computing purposes in the power industry. The Louisiana Power and Light Company's new Sterlington Station, engineered by Ebasco Services, Inc., will go on stream this spring with this equipment. In addition to routine scanning and logging functions, some of the objectives in the application of this equipment are:

1) Achievement of the high reliability necessary for power plant use,
2) Gain of "in-plant" operating experience with solid-state decision making equipment, aiming toward further improvement in plant safety and operation,
3) Acquisition of such important information as plant heat rate, calculated repetitively or "on demand",
4) Improve accuracy of flow measurements by computing coefficients for pressure, temperature, specific gravity, orifice temperature expansion, compressibility, etc.,
5) Ability to alter individual alarm limits automatically on the basis of other monitored information reflecting pertinent plant conditions such as plant load. This will provide close alarm limits on critical items previously impractical to monitor effectively.

Chalmer E. Jones, general manager of Daystrom Systems, discusses some of the features of an on-line computer controller for a power plant.

The system is designed to scan 250 temperatures at a nominal rate of 5 points per second, to log readings of 100 additional variables at scheduled times, and to permit the normal selection of the logging, or print-out, of any or all point readings or alarm set points, and to print the digital trend of any point being monitored.

The entire data processing is performed digitally with the exception of the input analog signal scanning. Immediately after selection of the signal by the multiplexing mercury-wetted relays, it is converted to a digital value by an analog to digital converter.

The heart of the system is a general-purpose computer which is the center of all activities. It, in turn, controls all other devices besides performing all computations and making logical decisions. It is an internally-programmed, single address machine with a random access magnetic core memory.

Since the system is to operate in a power plant where high-energy AC fields, DC control pulses, and varying ground potentials cannot be avoided, the system is designed in such a manner that the presence of such extraneous signals will not affect its operation. Furthermore, since a power plant must be maintained in continuous operation for 24 hours each day, unscheduled outage is critical. The availability guarantee of the equipment has therefore been set at ninety-nine percent over a six month period. The non-available time of one percent is defined as the total accumulated time that the equipment, except typewriters and printer, is out of service or not meeting accuracy requirements during plant operation.

Thus, a new standard in reliability has been established. Its realization necessitated that the prime design criterion, starting at the beginning with the logic of the machine, be directed without compromise toward this end. The result is that scheduled maintenance has been eliminated. Some of the details include the substitution of magnetic core memory storage for the conventional magnetic rotating drum, complete solid state circuitry with no vacuum tubes anywhere in the system, and the substitution of taper pin connections for the usual plug-in connectors on all circuit boards. The computer was originally designed for industrial control applications. While no control has been programmed for the Sterlington Station, the computer may be adapted for this purpose with the addition of peripheral equipment.

By applying the latest proven techniques, our well-qualified staff at Daystrom Systems is prepared to take single responsibility of assembling and installing a system to meet your needs. We are currently compiling a file of new applications and papers on various parts of systems, both industrial and military. If you are interested in receiving the file and periodic additions, please write us.

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Division of Daystrom, Inc., 5640 La Jolla Boulevard
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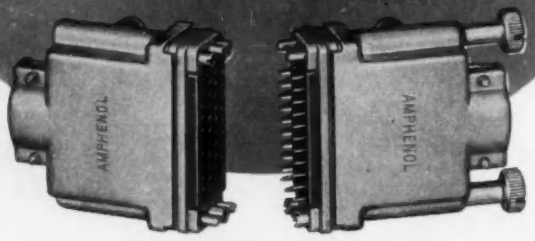
2 new

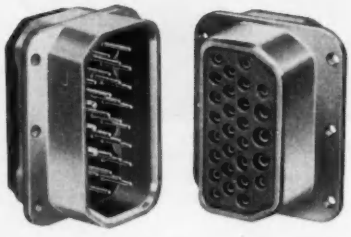
AMPHENOL

RACK & PANEL Series



93 SERIES

94 SERIES



both with POKE-HOME*contacts!

*U. S. PATENT 2,419,018

Meet 2 new additions to AMPHENOL's line of Rack & Panel connectors! The 93 and 94 Series are complete lines of standard connectors providing wide application variety. Both incorporate AMPHENOL's remarkable Poke-Home contacts that are wired separately from the connector then poked home for assembly. Poke-Home contacts are also removable for fast circuit changes or corrections.

93 SERIES 3 insert arrangements, 8 varieties of housings; 500 volts D.C. at sea level; 7½ amp size 20 contacts. Silicone rubber face gaskets. Operating temperature of 400°F. per MIL-C-8384.

94 SERIES 5 insert arrangements in 3 shell sizes; coaxial connectors in 2 inserts; 600 volts RMS at sea level; forged aluminum shells; temperature range of −76°F. to +257°F.

AMPHENOL

chicago 50, illinois

AMPHENOL ELECTRONICS CORPORATION

NEW PRODUCTS

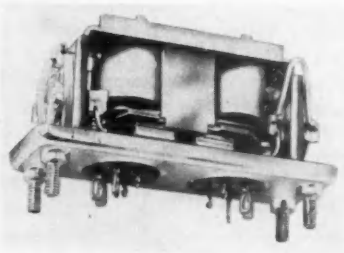
modulated temperature control, remote positioning, and synchronizing. Normal life is 10,000 hours and weight is under 2.25 lb.—Barber-Colman, Co., Rockford, Ill.

Circle No. 23 on reply card

LOAD CONTROL

Photo shows a load control relay for use with three-phase induction motors. The relay is sensitive to load changes in the order of 30 percent or less of a motor's rated load, and can be used to determine when a machine process has started, to end "spankout" on grinders, etc.—Machinery Electrification, Inc., Northboro, Mass.

Circle No. 24 on reply card

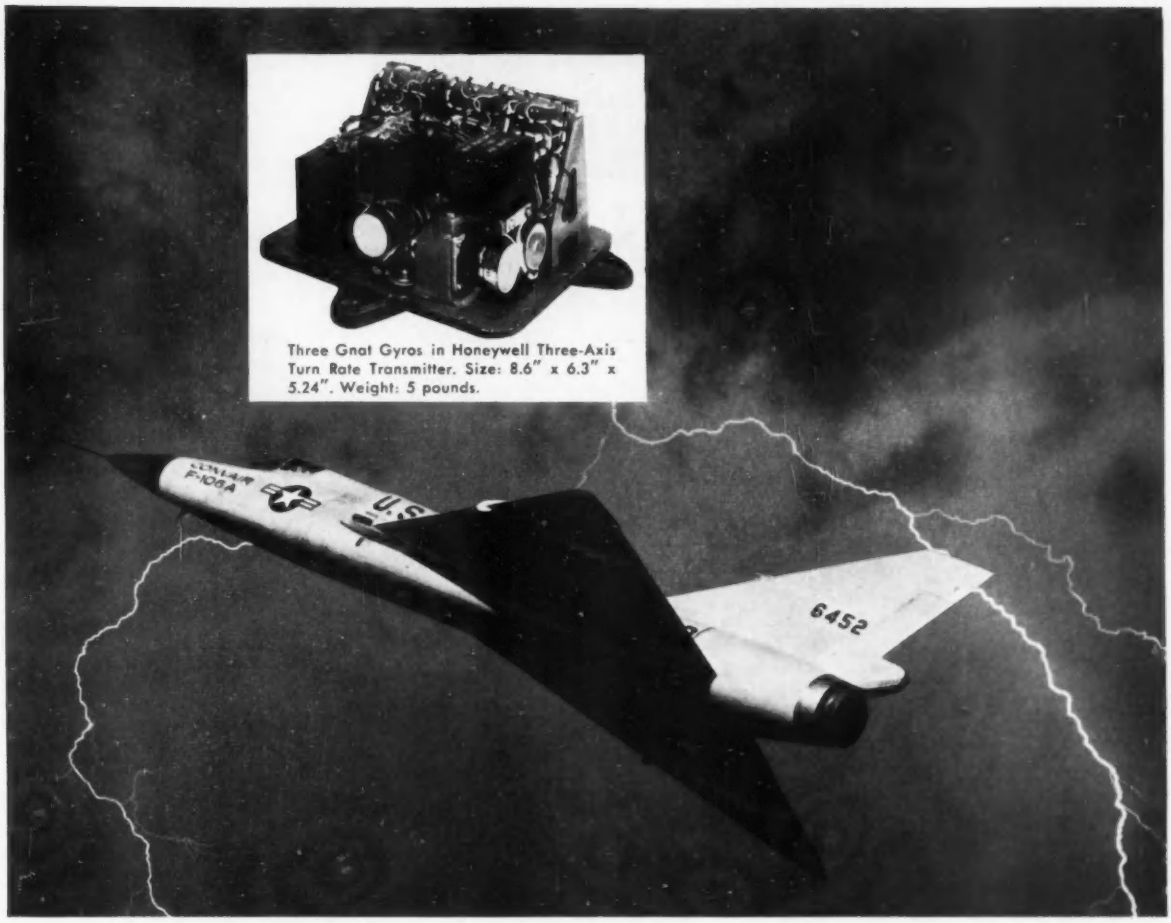


RUGGED RELAY

Designed for high shock and vibration, the KG11DG operates as a polarized relay or from two separate sources, one for operate, the other for reset. The device is normally pulse-operated but either of its coils may be left energized continuously.

Characteristics:

Load: Up to 30 amp at 30 vdc
Shock: Up to 100 g's



Three Gnat Gyros in Honeywell Three-Axis Turn Rate Transmitter. Size: 8.6" x 6.3" x 5.24". Weight: 5 pounds.

Convair F-106 all-weather jet interceptor incorporates Honeywell Three-Axis Turn Rate Transmitter in flight control damper system

Three-axis control at *all* speeds and altitudes

Gnat Rate Gyro shown ⅔ size. Weight: 3.8 ounces.

The Honeywell Three-Axis Turn Rate Transmitter, featuring three Gnat miniaturized gyros, was selected for the new Convair F-106 "Delta Dart" all-weather jet interceptor. Built into the stability augmentation sub-system of the jet's flight control system, the Transmitter detects rate of turn about the yaw, pitch and roll axes and responds with an output signal whose voltage is proportional to these input rates of turn.

This system is designed to operate under the most severe environmental conditions to which a combat aircraft might be subjected. The Honeywell Gnat Rate Gyros are easily capable of withstanding the severe shock, vibration and temperature requirements of this application and as such are mounted directly upon the base casting without shock mounts to optimize dynamic characteristics of the system.

The electronic portion of the Turn Rate Transmitter amplifies and demodulates the Gyro output signals to provide polarity reversing d-c outputs proportional to the corresponding input rate to each Gyro.

Investigate Honeywell's ability to develop, engineer and produce flight control systems for today's most advanced aircraft and missiles. Write for Bulletin GN to Minneapolis-Honeywell, Boston Division, Dept. 34, 40 Life Street, Boston 35, Mass.

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Military Products Group

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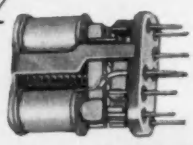
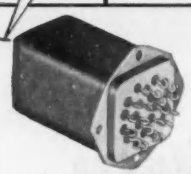


Series 1005 Relay
Micro-Miniature Control
L. 2⅞" W. 2⅝" D. 1½" (maximum)

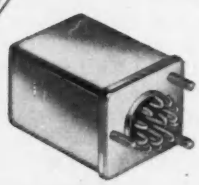
3 Amp Double Pole, Double Throw. Meets or surpasses requirements for all specifications of MIL-R-25018 and MIL-R-5757C. No exceptions. Contact Rating: 3 Amps at 125° C. per MIL-R-25018; 2 Amps at 125° C. per MIL-R-25018 and MIL-R-5757C Hermetically sealed. Specify plug-in or solder hooks.

$5.90 each in lots of one thousand f.o.b. Chicago, Ill.



Series 2005 Relay
Sub-Miniature Control
L 2¼" W. 1⅞" D. 1⅞" (maximum)

5 Amp 6 Pole, Double Throw. Meets or exceeds MIL-R-6106B and MIL-R-5757C. Built to withstand 100 G shock. Vibration resistance is 10 G minimum from 75 to 2000 c.p.s. in all mounting planes. All contacts rated at 5 Amps 24 to 30 v. D.C., resistive load. Operates with voltage variations as low as 16 v. at 25° C., ambient.



Series 3205 Relay
Miniature Control
L. 2½" W. 1²⁵⁄₃₂" D. 1⅞" (maximum)

10 Amp 4 Pole, Double Throw aircraft and missile relay uses same size envelope as AN 3304 (4 P.D.T. 3 Amp relay) and is approximately the same weight. Designed to meet and exceed test requirements of MIL-R-6106B, Class B. Meets minimum current requirements of military specifications.

Write for circulars giving complete specifications

GUARDIAN ELECTRIC
MANUFACTURING COMPANY
1623-G W. WALNUT STREET, *"Everything Under Control"* CHICAGO 12, ILLINOIS

NEW PRODUCTS

Vibration: 30 g's at 2,000 cps
Power required: 2.6 watts, 12 millisec
—Potter & Brumfield, Inc., Princeton, Ind.

Circle No. 25 on reply card

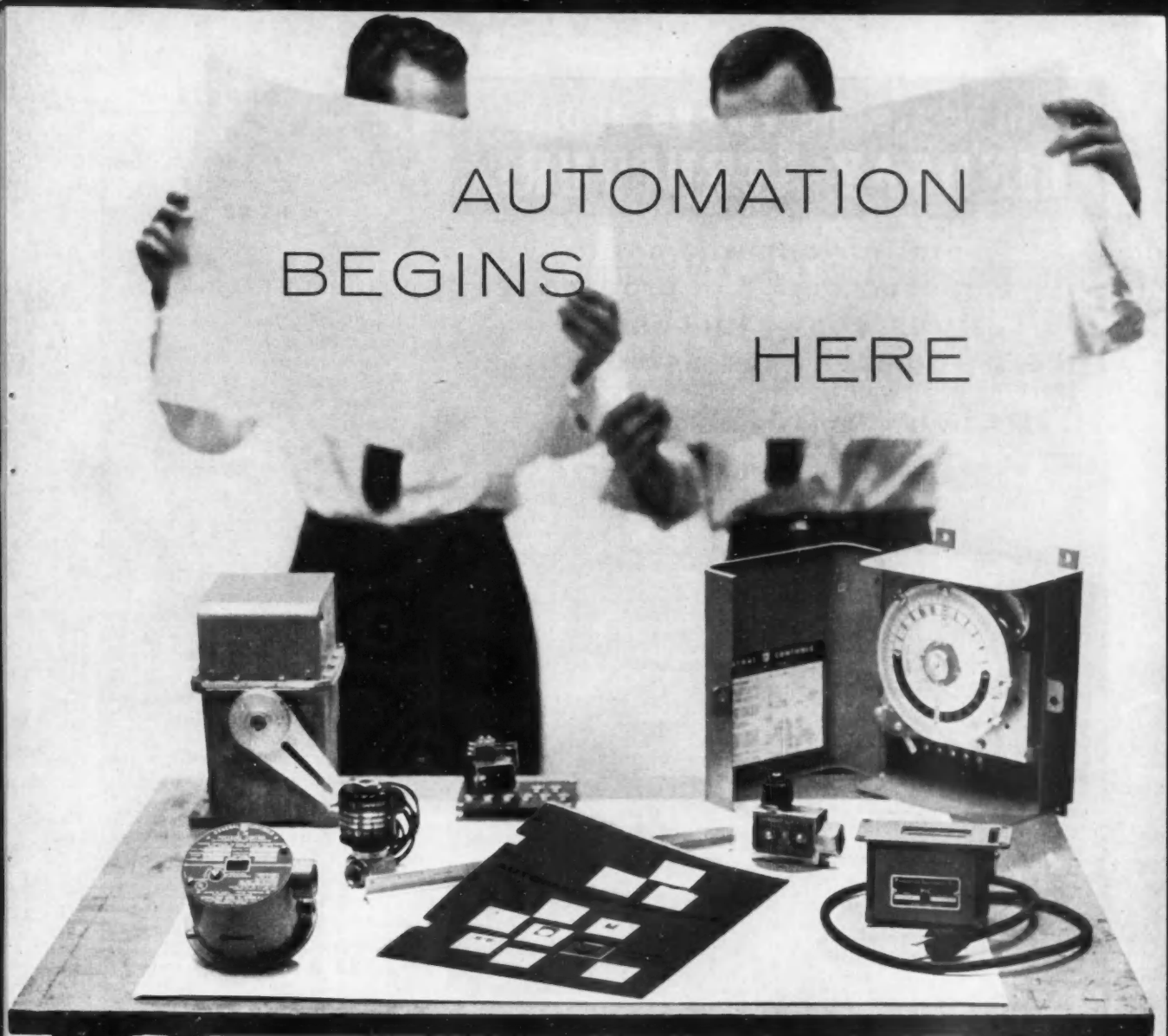
ROTARY SWITCH

Designed for sampling data from surveillance-type radars, sonars, and magnetometers, this rotary switch has three poles, 16 contacts per pole, and operates at 30 rps. One of each group of 16 contacts carries a reference voltage; each of the other 15 samples the response of a 25-deg cone.—Instrument Development Laboratories, Inc., Attleboro, Mass.

Circle No. 26 on reply card

OFF AND ON

This repeat cycle timer provides calibrated off and on cycles—off cycles from 1 to 300 sec, on cycles from 0.1 to 10 sec. Timer output is a double-pole, double-throw relay with 15-amp



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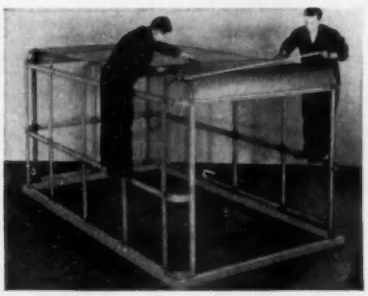
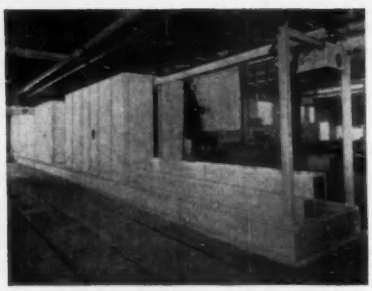


Lindsay Structure panel construction gives added strength for durability and economy. Equal tension in all directions makes a panel of greater strength than the original sheet, and highly resistant to impact damage. New lap-joint components make Lindsay virtually leakproof. For relatively small housings or enclosures Lindsay Structure carries its own weight . . . on larger or extended structures, enclosure with Lindsay is easy over a basic superstructure.

ADAPTABILITY TO DESIGN

Lindsay Structure is not limited by the general restrictions found in other forms of metal housing or enclosure. Easily adapted to stated requirements in length, width and height . . . can be built in any direction in fractional dimensions . . . with all the strength, durability and tightness of other forms of metal enclosure. Alteration in a basic Lindsay Structure is simple. Any dimension can be increased or decreased with ease due to Lindsay Structure special features.



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Uniform die-drawn, die-cut Lindsay components eliminate costly dies and tooling on your part. Lindsay Structure adaptability and elasticity allow for the building . . . to your exact design . . . of housings, enclosures, processing rooms and towers. All the information that is necessary for Lindsay engineers is the over-all dimensions, and locations of required openings. Assembly is easy, following instructions from Lindsay and using the least number of standard components.

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LINDSAY STRUCTURE DIVISION

INTERNATIONAL STEEL COMPANY

1425 Edgar Street | S | **Evansville 7, Indiana**

Canadian Affiliate: Lindsay-International, Ltd., Port Credit, Ontario

contacts.–G. C. Wilson & Co., Huntington, W. Va.

Circle No. 27 on reply card

TEMPERATURE CONTROL

A black box measuring less than 3 x 4 x 5 in. and weighing only 2 lb houses a pulse-modulated temperature control system. The unit is insensitive to vibration and shock up to 10 g's without special mounts.–Barber-Colman Co., Rockford, Ill.

Circle No. 28 on reply card

PLUS.....

(29) **Epsco, Inc.**, Boston, Mass., recently announced an airborne, subminiature, electronic **multiplexer series** with up to 40 channels. . . . (30) A sensitive machine load control from **Tipptronic, Inc.**, Chagrin Falls, O., protects against abnormal loading and single-phasing. . . . (31) **Micro Switch**, Freeport, Ill., has come out with a nylon-enclosed **mercury switch** with an spst contact arrangement. . . . (32) **Powers Regulator Co.**, Skokie, Ill., claims its new **pneumatic relay** can be installed with a screwdriver and wrench. . . . (33) A plug-in **limit switch** from **Square-D Co.**, Milwaukee, Wis., is designed for six different mounting arrangements.

Circle No. 29, 30, 31, 32 or 33 on reply card

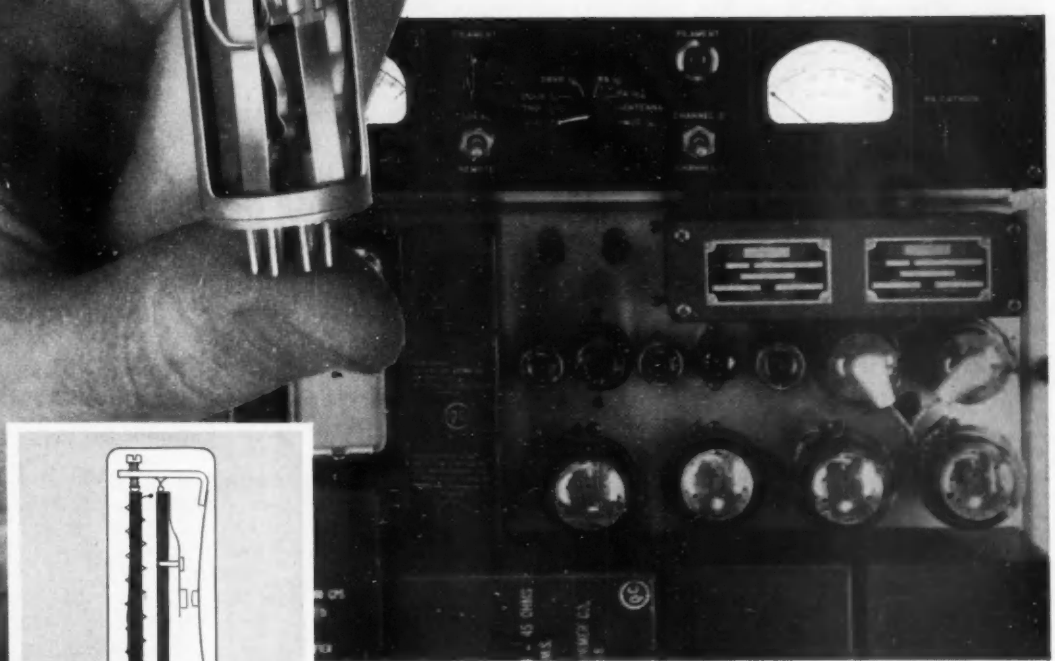
POWER SUPPLIES

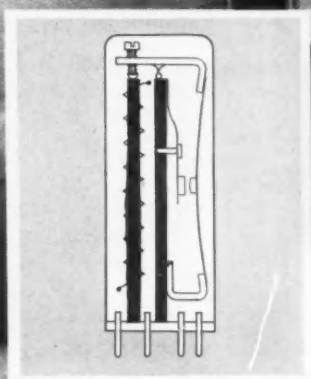
ELIMINATES DRY CELLS

The CVR-10, a constant-voltage reference supply, eliminates the need for dry-cell batteries in null-balance servo systems requiring a constant current dc voltage in a resistance bridge load. Dimensions of the new supply are the same as those of the dry cell, and its two knurled terminals

EDISON'S

model 250 miniature time delay relays are shock and vibration resistant





As heater causes the expansion member to stretch, lever pivots on its hinge, compressing the bow spring at a high rate in the direction of contact closure. Matching expansion member compensates for external changes in temperature between −65 and +100°C.

Designed to meet military requirements, Edison's line of miniature time delay relays are available for a wide range of electronic applications.

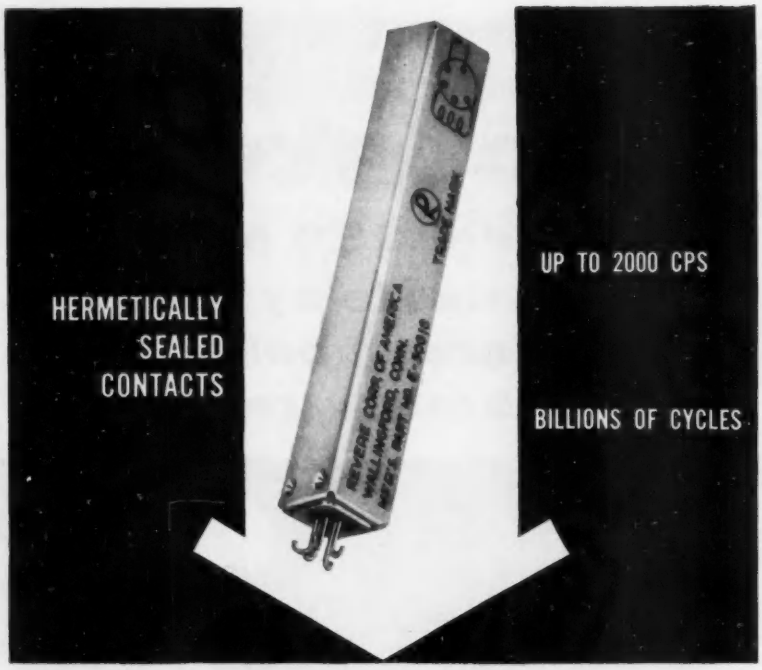
The 250 Series Time Delay Relays combine in one unit superior design, top workmanship and performance at lowest cost. Check these advantages:

- Designed to withstand vibration frequencies to 500 CPS.
- Exceptionally high rate of contact closure.
- Permanent calibration and hermetic seal.
- Extremely rigid mechanical structure using high-strength, high-expansion alloys.

For bulletin #3046 showing timing ranges and operating performance write to:

Thomas A. Edison Industries
INSTRUMENT DIVISION
38 LAKESIDE AVENUE, WEST ORANGE, N. J.

McGRAW EDISON



NEW...SPST Glaswitch* Relay

No possibility of contact contamination and shortened life in the Revere SPST GLASWITCH Relay. Reliability is built-in, with rhodium plated contacts hermetically sealed in a glass envelope containing dry nitrogen. Lightning response, 1 to 4 milliseconds . . . Modular design for easy stacking, with steel housing giving magnetic shielding . . . Long life, over 2 billion cycles.

This small, sensitive relay is used in many high speed switching applications. It is the switching component in the prototype models of a new, highly classified military computer, where relay reliability and long life are vital.

The SPST GLASWITCH Relay is offered in four standard coil voltages: 6, 12, 24 and 48 V.D.C. Other coil voltages can be provided. Dual coils for locking and permanent magnet biasing for NC operation can be furnished. 2PST and 4PST also available. Special designs to order.

*Trademark

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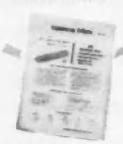

65

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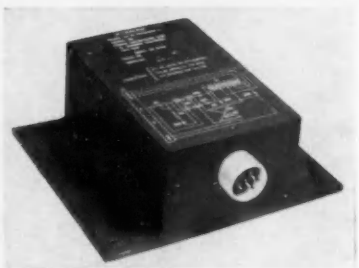
neptune

NEW PRODUCTS

correspond to the terminals of the battery. Three leads provide for connection to a 115-volt line and ground at the instrument. Stability over line voltage variations, between 108 and 125 volts, is within ¼ percent.—Performance Measurements Co., Detroit, Mich.

Circle No. 34 on reply card



400 CYCLE AC

Built to military specs, this new magnetic amplifier, regulated ac power supply is being offered for general systems applications.

Characteristics:

Input: 108-121 volts, single phase, 380-420 cps
Output: 5.7-7.5 volts rms, 2.5-5 amp, 400-cycle, single-phase
Temperature range: minus 40 to plus 150 deg F
Regulation accuracy: within plus or minus 1 percent
—Perkin Engineering Corp., El Segundo, Calif.

Circle No. 35 on reply card

PLUS.....

(36) **Sorenson & Co., Inc.**, South Norwalk, Conn., offers a **dc power supply** with a controlled power capacity of 4,000 watts. . . . (37) For a rocket engine test stand, **Western Gear Corp.**, Lynwood, Calif., has built a 72-channel **strain gage power supply.** . . . (38) **A two-phase power supply,** with a total power output of over 500 va, is available from **Pacific Technical Co.**, Los Angeles, Calif. . . . (39) **P. R. Mallory & Co.**, Indianapolis, Ind., has made available experimental production quantities of a new 0.9-volt **chargeable dry cell** that measures only 1.190 in. in diam by 0.591 in. high.

Circle No. 36, 37, 38 or 39 on reply card

All-in-one selector switch—indicating light by Westinghouse.

A start button, a stop button, an indicating light—all in one handsome, compact selector unit.

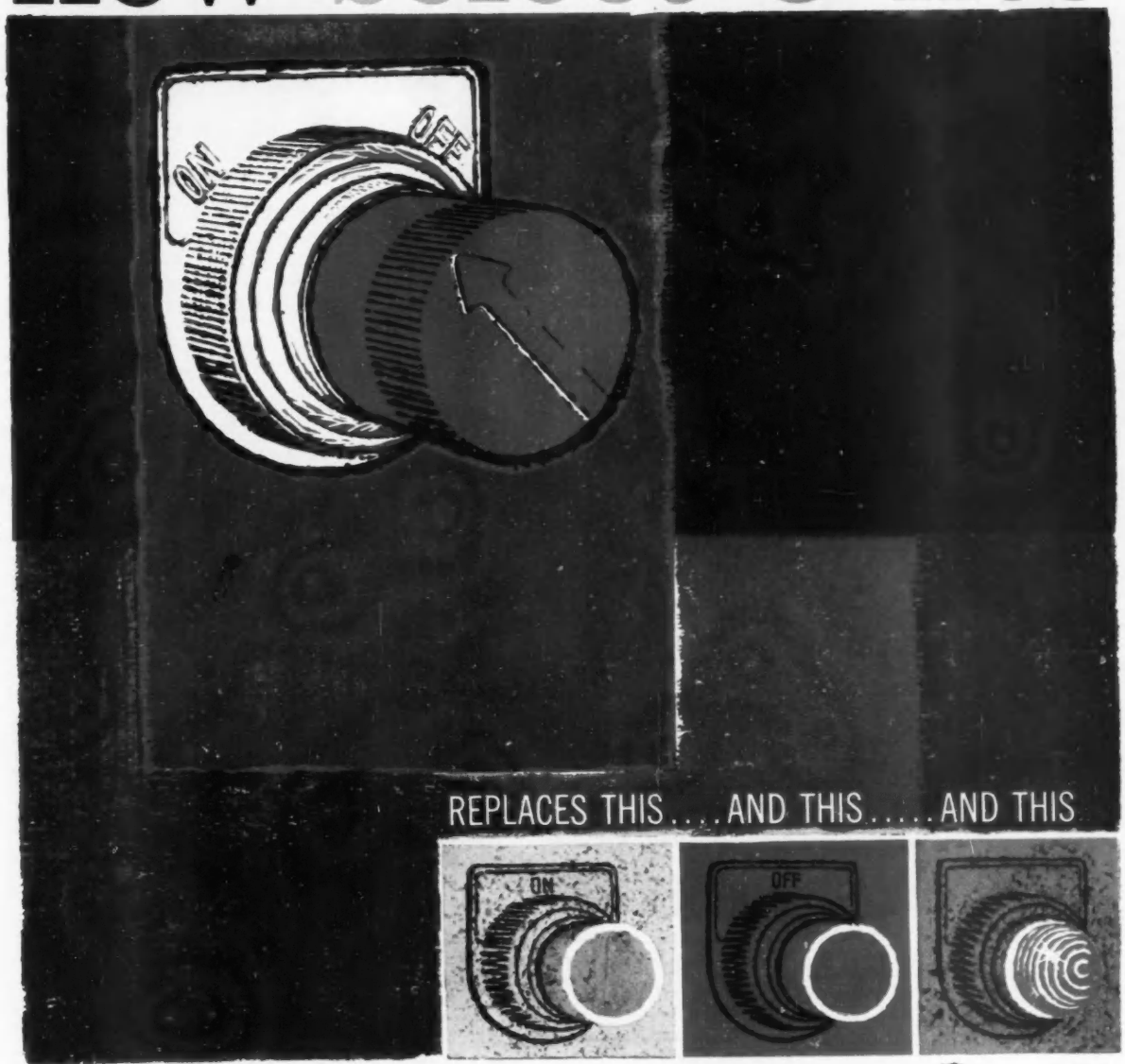
Saves **up to 60% on panel space!**

Saves **considerable initial expense!**

They're oil-tight, of course—with a panel-enhancing chrome finish—a lifetime operation snap-acting switch—and interchangeable nameplates for on-off, start-stop, forward-reverse. Or any combination you choose.

You can get full information, and a supply of Westinghouse selector-switches, by contacting your Westinghouse sales office or distributor. Or write the Westinghouse address shown below.

new select-O-lite



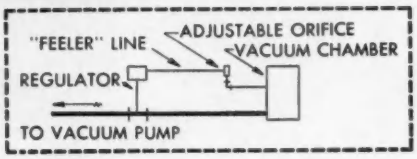
J-30296

YOU CAN BE SURE...IF IT'S **Westinghouse**

Westinghouse Electric Corporation
STANDARD CONTROL DIVISION
Beaver, Pennsylvania

VACUUM
REGULATION
...Fulton Sylphon is your No. 1 source!
Simple! Compact! Powerful! All-metal Fulton Sylphon No. 994 Vacuum Regulator provides superior performance at low cost in low pressure and vacuum service. Dependable, large-size Sylphon® Metal Bellows and tension-compression loading spring assure accurate control and long life. Widely used in food, chemical and pharmaceutical processing. Models available to provide reduced pressures from −14 to +20 psi. National field service . . . complete engineering assistance. Write for Bulletin TP-103-JG.

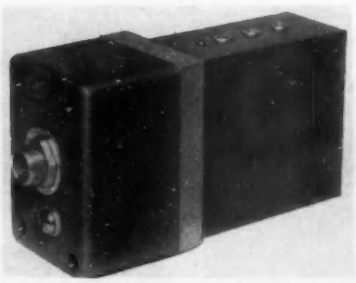
Typical vacuum regulator application—reverse-acting valve closes when the vacuum increases.



Robertshaw-Fulton CONTROLS COMPANY

FULTON SYLPHON DIVISION
Knoxville 1, Tennessee

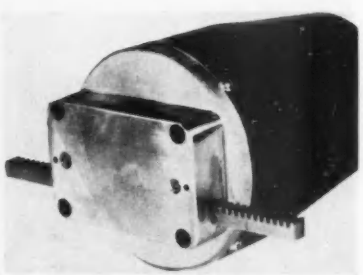
ACTUATORS & FINAL CONTROL ELEMENTS



ONLY FOUR MOVING PARTS

Designed for industrial and ground ordnance applications, this two-stage electrohydraulic servo valve contains just four moving parts: main spool, control spool, sleeve, and feedback linkage. The mechanical feedback linkage, with variable fulcrum, gives the valve great flexibility and makes it compatible with varying conditions of flow, response, and pressure. Unit handles a maximum of 10 gpm at 1,000 psi, and operates with supply pressures as high as 3,000 psi and as low as 300 psi. Specific applications include machine tools, processing lines, variable speed drives, and missile handling equipment.—Vickers, Inc., Detroit, Mich.

Circle No. 40 on reply card



LINEAR ACTUATOR

The linear actuator is designed for use in systems where linear motion must be proportional to a control signal. This one has a gear motor with built-in potentiometer to indicate position. The actuator can be governed by control signals from any transducer—control signal may be 3 to 15 psi, 0.5 to 5 ma, or a variable frequency source.

DELCO'S FAMILY OF HIGH POWER TRANSISTORS

Typical Characteristics at 25°C

	DT100	DT80	2N174A**	2N174	2N173	2N443	2N278	2N442	2N277	2N441
Maximum Collector Current	13	13	13	13	13	13	13	13	13	13 amps
Maximum Collector Voltage (Emitter Open)	100	80	80	80	60	60	50	50	40	40 volts
Saturation Resistance (13 amp.)	.02	.02	.02	.02	.02	.02	.02	.02	.02	.02 ohms
Max. Square Wave Power Output at 400~P-P*	400	310	310	310	225	225	180	180	135	135 watts
Max. Sine Wave Power Output at 400~P-P*	180	140	140	140	100	100	80	80	60	60 watts
Power Dissipation (Stud Temperature 25°C)	70	70	70	70	70	55	55	55	55	55 watts
Thermal Gradient from Junction to Mounting Base	1.0°	1.0°	1.0°	1.0°	1.0°	1.2°	1.2°	1.2°	1.2°	1.2° °C/watt
Nominal Base Current I_B (V_{EC} = −2 volts, I_C = −1.2 amp.)	-19	-13	-19	-19	-13	-24	-13	-24	-13	-27 ma

*Adequate Heat Sink

**Designed to meet MIL-T-19500/13 (USAF) 18 JUNE 1957

Performance characteristics to meet your switching, regulation or power supply requirements

These ten Delco Radio alloy junction germanium PNP power transistors are now in volume production. They are characterized by high output power, high gain, and low distortion. And all are normalized to retain superior performance characteristics regardless of age.

Check the data chart above—see how they fit your particular requirements in current switching, regulation or power supply. Write for detailed information and engineering data. Delco Radio maintains offices in Newark, N. J. and Santa Monica, Calif. for your convenience.

BRANCH OFFICES

Newark, New Jersey
1180 Raymond Boulevard
Tel: Mitchell 2-6165

Santa Monica, California
726 Santa Monica Boulevard
Tel: Exbrook 3-1465

DELCO RADIO
Division of General Motors
Kokomo, Indiana

The heat's on, as withering high temperatures are applied... and once more G-M Servo Motors prove themselves!

This cruel high-temperature exposure in electric ovens at the G-M Laboratories is only one part of a rigorous test series G-M Servo Motors must undergo—prior to use in rocket and missile applications.

At G-M, Servo Motors are proved under all military environmental specifications called for. They are built to withstand the tortures of humidity, salt spray, altitude, vibration and both high and low temperatures. And they pass with honors.

4 GOOD REASONS WHY G-M SERVO MOTORS SERVE YOU BEST!

1. G-M Servo Motors are available in standard sizes.
2. G-M Servo Motors can be modified to meet specific circuit requirements.
3. New "Stock Sample Service" for quick delivery of standard motors for prototype use.
4. Fast production—better service.

GM

G-M Servo Motors

manufactured by the Components Division of

G-M LABORATORIES INC.

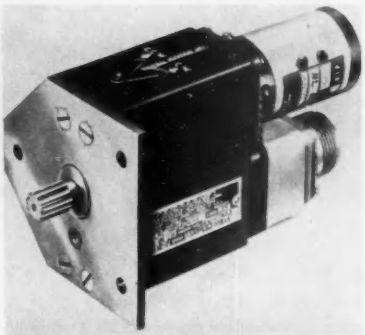
4320 N. Knox Avenue • Chicago 41

Write Now for information, or send for complete G-M charts and specifications. No obligation, of course.

NEW PRODUCTS

Rack and pinion output thrusts up to 1,000 lb are available. The Jordan Co., Milwaukee, Wis.

Circle No. 41 on reply card



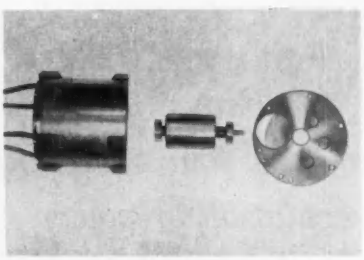
40 ROTARY ACTUATORS

Forty different rotary actuators can be assembled from this new 12-component package.

Characteristics:

Available units: low and high-power motors, ac and dc; low-intermediate and high-gear reduction sections; accessory drives or transmitters; mounting flanges or output shafts
Load ratings: to 100 lb per in.
Speeds: 0.5 to 50 rpm
Weight: dc unit: 0.9 lb; ac unit: 1.1 lb
Current: 115 volts, 400-cycle ac, or 26 volts dc
—Airborne Accessories Corp., Hillsdale, N. J.

Circle No. 42 on reply card



WORKS AT 600 DEG F

Shown is a two-phase servomotor which operates in 600 deg F ambient air to produce a torque of about 150 oz-in. at 30 rpm. Size and weight: 2.8 in. diameter, 2½ lb.—Thompson Products, Inc., Cleveland, Ohio.

Circle No. 43 on reply card

STOPPED!

LOST *10,000 man-hours*

and your high-paid help talks TV

Stopped . . . because automatic control circuits and operating elements were not designed on the modular basis, with Cannon quick-disconnect electrical connectors at vital points.

But it could have been rolling in seconds or minutes! If only the circuitry had been arranged on the modular basis so that essential elements of the automatic control and operating system could be disconnected quickly . . . and complete, operable spare components inserted at a moment's notice. The units in trouble could have been repaired properly, too, at leisure . . . by trained personnel, at the right place, with the right facilities. Production could have gone on . . . thousands of man-hours and thousands of dollars saved . . . merely by the use of quick-disconnect components.

Are the controls in your electrical or electronic product designed on the modular basis? How about your production line? Will minor failure cause breakdown? Or do you need Cannon Connectors? Cannon makes over 27,000 different electrical connectors. If one of these does not meet your requirements, we'll design and make the electrical connector you need. Write today! Cannon Electric Co., 3208 Humboldt St., Los Angeles 31, Calif. Please refer to Dept. **422.**

Send for explanatory material on how modular designs can save dollars.

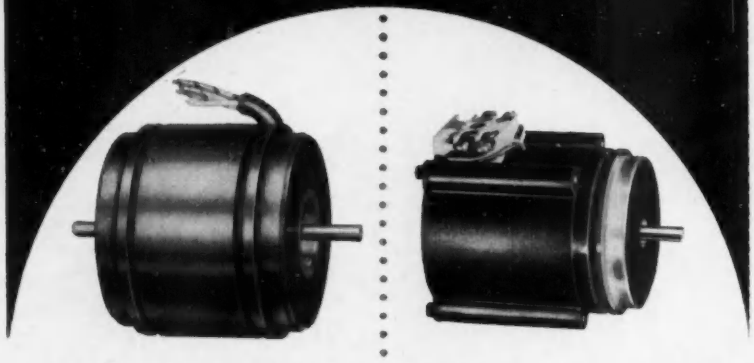
CANNON PLUGS

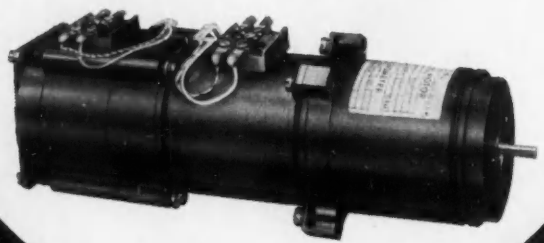
CANNON ELECTRIC

Where Reliability for Your Product is Our Constant Goal

COPYRIGHT 1958, CANNON ELECTRIC CO.

DIEHL*
Servo Package





MOTOR • GEAR TRAIN • A.C. or D.C. TACHOMETER
In One Convenient Package
. . . also available in separate units

Now DIEHL has quality components *packaged* to save you assembly time and trouble. The new DIEHL integrated servo package comes completely assembled, ready for installation. Geared for fast response, the package is competitively priced for commercial applications.

SERVO MOTOR is two phase 60-cycle–high torque to inertia —high or low impedances for transistor, vacuum tube, or magnetic amplifiers.

GEAR TRAIN is of rugged, precision-built construction—can carry a continuous torque load of 100 oz. inches.

A.C. TACHOMETER GENERATOR has linearity accurate enough for use as an integrator in many computing systems.

All units meet MIL Specifications

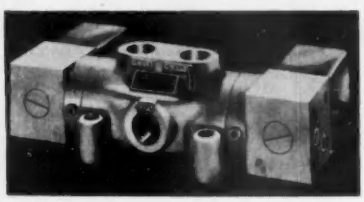
DIEHL design engineers will be happy to work with you in providing custom-built servo equipment for your specific needs. Send for additional engineering data.

DIEHL MANUFACTURING COMPANY
Electrical Division of THE SINGER MANUFACTURING COMPANY
Finderne Plant, SOMERVILLE, N. J.

Other available components:
RESOLVERS • A.C. AND D.C. SERVOMOTORS • SERVOPOTS

*A Trademark of DIEHL MANUFACTURING COMPANY

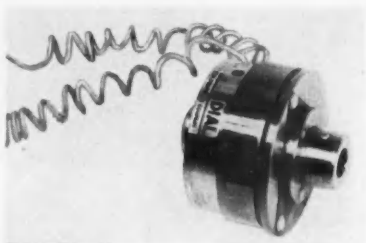
NEW PRODUCTS



FOR OIL SYSTEMS

This control valve for hydraulic oil systems is available in six different models, differing in their method of operation; they can be operated by lever, stem, cam, oil pilot, air pilot, or solenoid-controlled oil pilot. Most models are available in a choice of spool styles, and in two pipe sizes, ½ and ¾ in.—The Dukes Co., Schiller Park, Ill.

Circle No. 44 on reply card



STATIONARY ARMATURE

The stationary armature in this new magnetic clutch eliminates the need for slip rings or brushes. A flexible membrane pole shoe assembly provides zero backlash and zero residual drag, and allows 3 deg angular misalignment between the driving and the driven shafts. Both diameter and length are less than 2 in., power consumption less than 4 watts, minimum torque 7 in.-lbs.—Dial Products Co., Bayonne, N. J.

Circle No. 45 on reply card

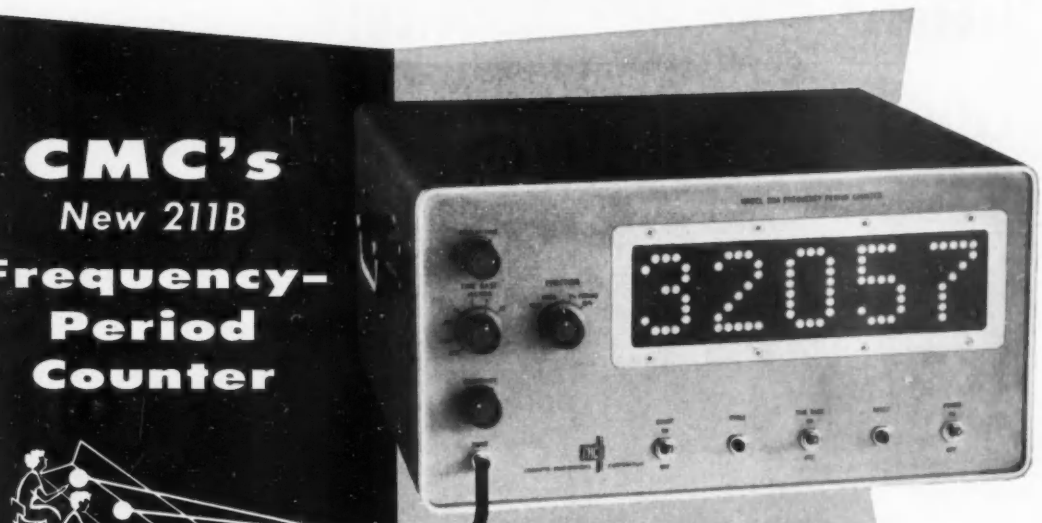
PLUS. . . . . .

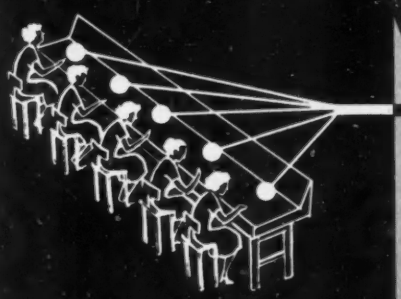
(46) High-pressure **control valves** in sizes up to 14 in. are available from **Conoflow Corp.**, Philadelphia, Pa. . . . (47) **United Hydraulics Inc.**, Dayton, O., has a 3,000-psi **metering valve** operated by a small, direct-coupled 3-15-psi air pressure diaphragm. . . . (48) The D1890 **linear actuator** made by **Hoover Electric Co.**, Columbus, O., operates under a normal load of 860 lb at a rate of 0.28 in. per sec.

Circle No. 46, 47 or 48 on reply card

SOUNDEST SOLUTION TO EVENTS-PER-UNIT TIME MEASUREMENTS

CMC's New 211B Frequency-Period Counter





Inline-inplane readable readout with 2¼" numerals

0 to 220kc frequency range... 10 microsecond to 100,000 second period range

Memory circuit holds displayed readings while counter cycles to accumulate new data

FEATURES: *Automatic decimal point indication • Six gate times and external position • Costs 20% less than separate units • Modular plug-in printed circuit construction • Readings clearly visible at high ambient light level for more than 150 feet • Temperature regulated crystal controlled time base.*

CMC's new 211B Frequency-Period Counter combines high speed electronic counting and inline-inplane digital presentation in one compact, convenient and economical package. Each digit consists of 40 small, long life neon lamps. Reading errors caused by lamp filament failure occurring in edge lighted, segment-masked, or projection type illumination are eliminated. Memory circuit provides the latest available information at the time of reading. Digits do not cycle during the counting period.

Here is a new instrument ideally suited to laboratory and production testing. One 211B serves five or six bench positions (see sketch) cutting requirements for instrumentation accordingly. At the same time accuracy of readings is increased owing to CMC's unique fail-safe presentation. The new counter is also particularly appropriate for "block house" use where readings must be taken from a safe distance. Instances of this application are jet or piston engine test cells, dynamometer test stands, nuclear radiation measurements, and missile countdown tests.

Other applications include hydraulic and servo testing, calibrating frequency generating equipment, testing crystals, frequency stability checks, and measurements of all basic physical quantities such as pressure, flow, RPM, velocity, etc.

KEY SPECIFICATIONS

FREQUENCY MEASUREMENT	
FREQUENCY RANGE	1 to 220,000 cps 0 to 220,000 positive pps
INPUT SENSITIVITY	0.07 volt rms: 1 to 10 cps 0.05 volt rms: 10 to 100,000 cps 0.1 volt rms: 100kc to 220kc
ACCURACY	±1 count ± stability
TIME BASES	0.0001, 0.001, 0.01, 0.1, 1, 10 seconds crystal controlled
PERIOD MEASUREMENT	
PERIOD RANGE	10 microseconds to 10^5 second
FREQUENCY RANGE	1 to 100,000 cps 0 to 100,000 positive pps
INPUT SENSITIVITY	0.07 volt rms: 1 to 10 cps 0.05 volt rms: 10 to 100,000 cps
ACCURACY	±1 count ± stability
GENERAL	
STABILITY	Short Term: 1 part per million Long Term: 5 parts per million
PRICE	$1175 f.o.b. factory

CMC engineering representatives are located in principal cities. After you've checked over the key specifications, give your nearest CMC representative a call. He'll be happy to arrange a demonstration. For complete technical information, please write Dept. 086.

Computer-Measurements Corporation
5528 Vineland Ave. • No. Hollywood, Calif.
Phone STanley 7-0401 • TWX: NHOL 2160

Subsidiary of Hancock Industries

5

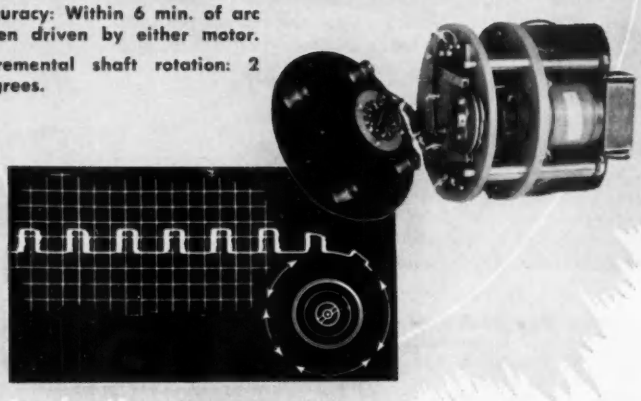
COMMAND SIGNAL GENERATOR — COMMAND SIGNAL RECEIVER — SYNCHRO POSITIONER — AUTO PILOT CONTROL

LEFT
RIGHT
CLIMB
DESCEND

STEPPER
SYNCHRO POSITIONER

Accuracy: Within 6 min. of arc when driven by either motor.

Incremental shaft rotation: 2 degrees.



This is one of the many applications for the Stepper Motor — a device for translating electrical pulses into accurate, bi-directional, incremental shaft displacements.

The Synchro Positioner uses two Stepping Motors, an Autosyn differential, and a built-in pulse generator. One motor positions the Autosyn Shaft in coarse increments in either direction, while the other motor, using a different gear ratio, positions the same shaft in vernier increments in either direction. As the reset command signal is of steady-state type, the built-in pulse generator permits use of the driving motors for the reset function.

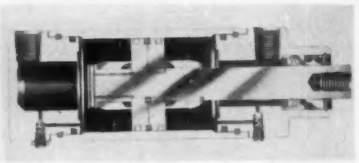
STEPPER MOTORS CORPORATION

Subsidiary of California Eastern Aviation, Inc.

7442 West Wilson Avenue • Chicago 31, Illinois

• WEST COAST · · · 11879 W. FLORENCE AVE. · · · CULVER CITY, CALIF.

NEW PRODUCTS

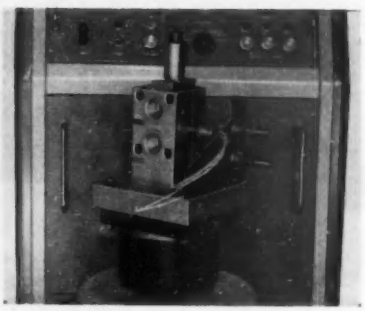


HOT CYLINDERS

Operational range of the air and hydraulic cylinders shown is minus 20 to plus 500 deg F. Pressure service ratings for the air cylinders: to 150 psi; for the hydraulics, 350 psi.—Carter Controls, Inc., Lansing, Ill.

Circle No. 49 on reply card

RESEARCH, TEST & DEVELOPMENT



FUNCTION GENERATOR

The Functionair Model 100 pneumatic function generator provides pneumatic pressures for use in testing and simulating pneumatic control systems and components.

Characteristics:

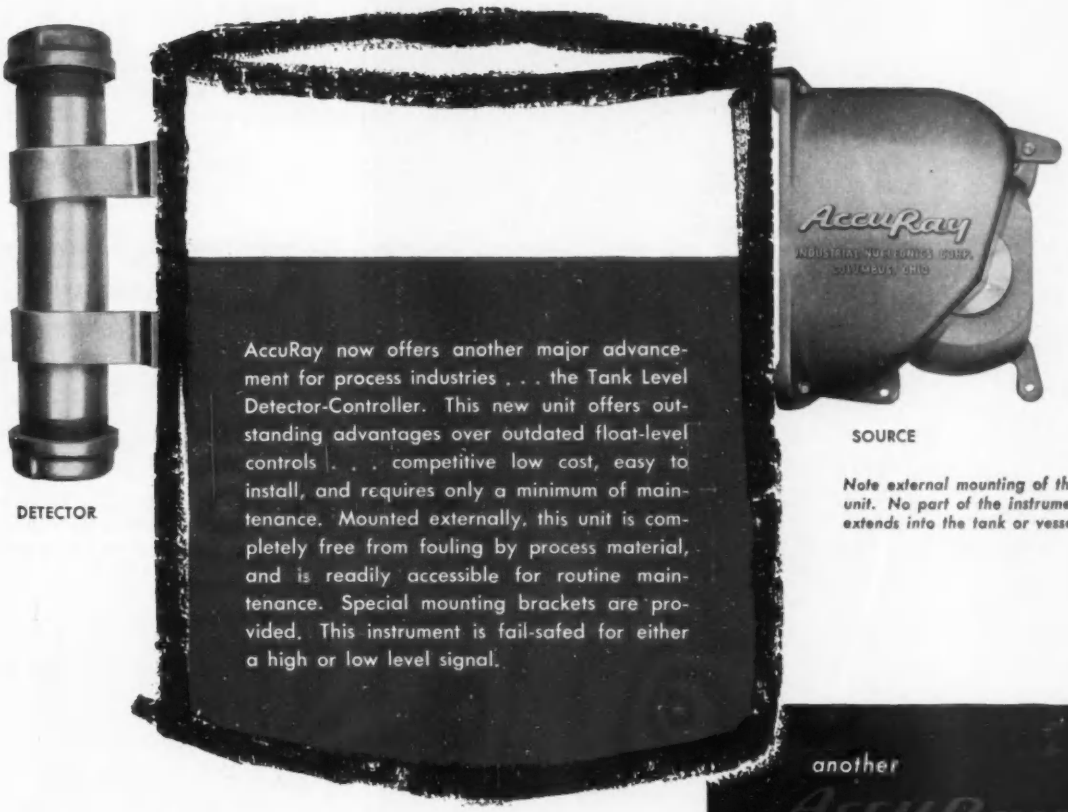
Static accuracy: 1 percent full-scale.
Operating pressures: 5 to 100 psi
Frequency response: dc to 50 cps
Max flow at 50 cps: 0.01 lb air per sec
Supply air temp: minus 65 to plus 200 deg F
Power: 117 vac, 60 cps, 900 watts
—Palisades Engineering Co., Pacific Palisades, Calif.

Circle No. 50 on reply card

LEAK DETECTORS

A new line of halogen-type leak detectors features four detector heads for use with one standard control unit. Applications of the detectors include

AccuRay TANK LEVEL DETECTOR-CONTROLLER



DETECTOR

SOURCE

Note external mounting of the unit. No part of the instrument extends into the tank or vessel.

AccuRay now offers another major advancement for process industries . . . the Tank Level Detector-Controller. This new unit offers outstanding advantages over outdated float-level controls . . . competitive low cost, easy to install, and requires only a minimum of maintenance. Mounted externally, this unit is completely free from fouling by process material, and is readily accessible for routine maintenance. Special mounting brackets are provided. This instrument is fail-safed for either a high or low level signal.

another AccuRay® advancement for process control

The AccuRay Tank Level Detector-Controller can be used in two ways. It can be installed horizontally to provide a relay closure signal when the level rises above or falls below the level of the detector; or it can be installed vertically so that both a high level and a low level signal can be provided from one instrument. Accuracies can be maintained to plus or minus 1/16". The radiation source is installed either opposite the detector on the tank, or across a chord of the tank. The design of the source housing provides more than adequate shielding. Design of the instrument is in accordance with accepted standards for both explosion-proof and weatherproof operation.

®*AccuRay is a Registered Trademark of Industrial Nucleonics Corporation*

Industrial Nucleonics CORPORATION

1159 Chesapeake Ave., Columbus 12, Ohio

Please send complete details on AccuRay Tank Level Detector-Controllers.

Name ..... Title .....

Company .....

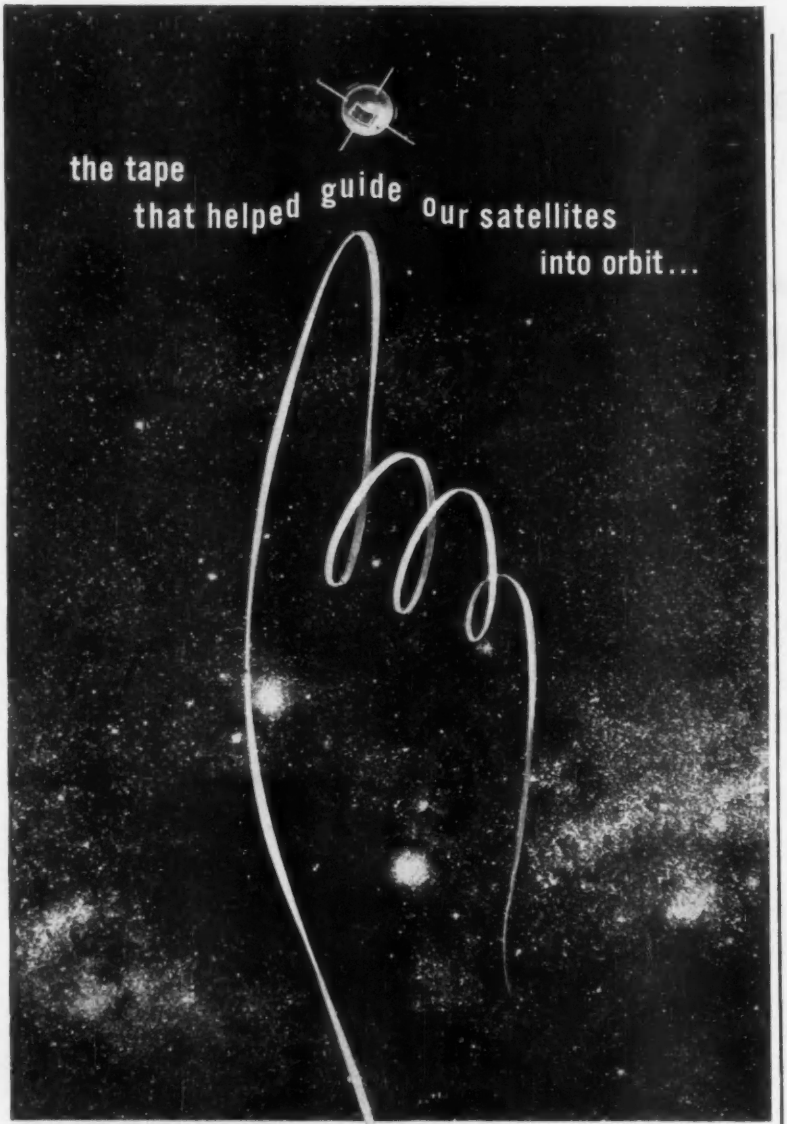
Street .....

City ..... Zone ..... State .....

Application .....

.....

The WORLD'S LARGEST Manufacturer of Nucleonic Industrial Process Control Systems



SOUNDCRAFT TYPE A TAPE FOR DIGITAL RECORDING

The Ford Instrument guidance system in Army Jupiter-C missiles that launched the Explorers into space... and the recording system in the Navy's Vanguard... employed a most reliable magnetic medium — Soundcraft Type A Tape. Only Soundcraft Type A Tape has electrical and physical stability to merit selection in these vital missions ...and in your own instrumentation applications. The RCCH oxide formulation in Type A Tape provides higher signal output and greater retentivity ... plus unique surface hardness and high thermal stability. Soundcraft's exclusive Micro-polishing and Uni-level coating processes help provide the electrical and physical uniformity found only in Soundcraft Type A Tape. Send for detailed Type A Brochure!

One tape can't serve all needs...For Your Telemetering Applications... write for brochure on Soundcraft Type B Tape for Telemetering!

REEVES SOUNDCRAFT CORP.

Dep't CE, 10 East 52 St., New York 22 • West Coast: Dep't CE, 342 N. La Brea, Los Angeles 36 R49

NEW PRODUCTS

missile, aircraft, and nuclear reactor testing.

Characteristics:

Sensitivity: down to 10^{-6} cc per sec
Operating voltage: 120/240 volts 50-60 cps
Probe types: gun, pencil, stationery, and vacuum-system types
—General Electric Co., Schenectady, N. Y.

Circle No. 51 on reply card

IN-LINE READOUT

This counter-timer for lab applications feature in-line display of information. It measures frequency to 1 megacycle, time in 1-microsec increments, phase angles in 0.1-deg increments, and events to seven digits.—Systron Corp., Concord, Calif.

Circle No. 52 on reply card

1½ CUBIC FEET

The APAC (Airborne Parabolic Arc Computer) weighs less than 100 lb, contains its own power supply, and occupies only 1½ cu ft. Input is punched-tape, memory is magnetic-drum type. The computer is divided into 19 plug-in assemblies for easy repair.—Northrop Aircraft, Inc., Hawthorne, Calif.

Circle No. 53 on reply card

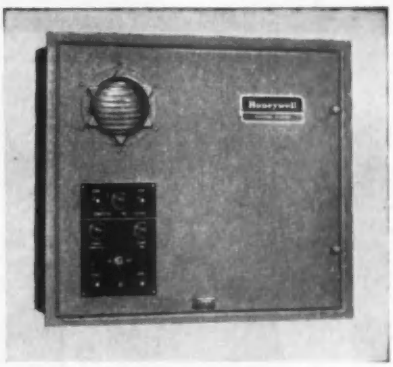
PLUS.....

(54) **Beckman-Helipot Corp.**, Newport Beach, Calif., offers a new **servo kit** with 262 parts in a well-designed storage carton. . . . (55) An **ultra-high impedance VTVM** by **Rheem Mfg. Co.**, Rivera, Calif., features a built-in memory that holds measurements for several hours. . . . (56) **Kingston Electronic Corp.**, Medfield, Mass., has developed a new **waveform analyzer** that uses an electrostatic coupling probe to eliminate the need for physical connections.

Circle No. 54, 55 or 56 on reply card

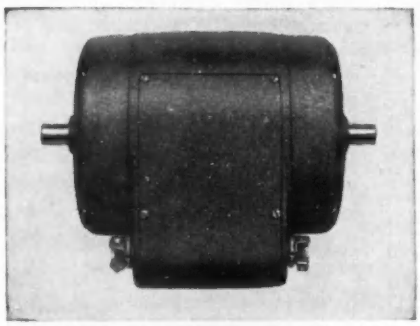
PRESSURE CONTROLLERS for high or low-limit cutoff or signalling, or for control of pressure and vacuum in many ranges from 0 to 1000 psi.

REMOTE BULB TEMPERATURE CONTROLLERS for high or low-limit cutoff . . . signalling . . . and automatic on-off, two-position, floating or proportional control with electrically or pneumatically operated valves, dampers, refrigeration units and similar equipment.

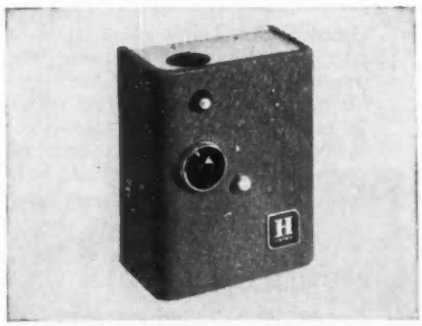


***PROTECTOGLO* FLAME SAFEGUARDS** instantly detect flame failure in gas or oil fired burners, and immediately shut off fuel supply, sound an alarm, and perform other functions to guard against explosion hazards.

Add low-cost automation ...with Honeywell industrial controls



INDUSTRIAL MOTORS for electrical operation of valves, dampers and auxiliary switches.



ALARM SILENCING RELAYS permit an alarm to be silenced, and light an integral red light until an unsafe condition has been corrected. Relay automatically resets the alarm when safe conditions are restored.

You don't have to spend a lot of money for dependable automatic controls. Like many manufacturers, you can use various Honeywell industrial controls as the efficient, low-cost means of automating your equipment . . . improving performance . . . increasing safety. And, you can use these inexpensive controls to save time, money and space by extending automation in your plant or process.

There are more than 9000 standard types of Honeywell controls to handle temperature, pressure, liquid level and humidity—for control, switching or safety functions. There are electric, electronic and pneumatic types.

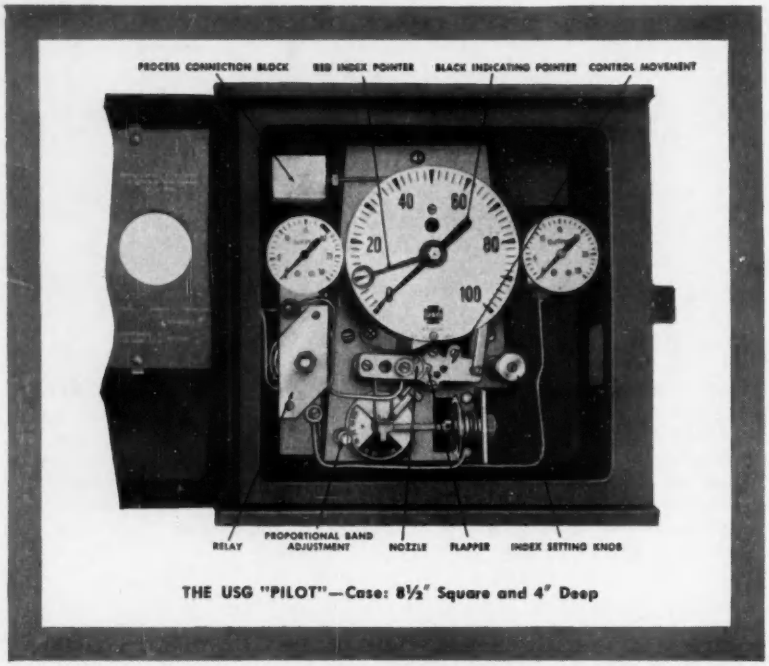
Though they're low in cost, these controls are top-quality, reliable devices. If there's not already a standard control for your particular application, Honeywell can design and build one for you.

Your nearby Honeywell field engineer will be glad to discuss your control requirements. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Honeywell

First in Controls



THE USG "PILOT"—Case: 8½" Square and 4" Deep

A COMPACT, LOW-COST*

INDICATING PNEUMATIC CONTROLLER

for pressure . . . temperature . . . other variables

(1) Control modes to suit your process: Two-position with differential gap (1 to 100%) . . . proportional (1 to 150%), alone or with automatic reset or rate action. Control mode or control action (direct or reverse) easily altered in field.

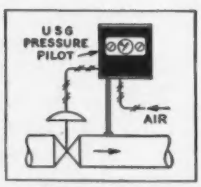
(2) Variable and set point both indicated on large dial: Black pointer indicates reading on 3½-inch dial (6¾-inch scale length). Red circle-tipped pointer spots location of set point.

(3) High accuracy and sensitivity at low cost: Accuracy of 1% of range over middle half of scale. Sensitivity less than 0.1% of scale at 100% proportional band setting . . . compares favorably with higher-priced controllers.

(4) Simplified maintenance and repair: Precalibrated measuring element can be removed for range change. Other basic components, even entire control chassis, can be removed for easy maintenance.

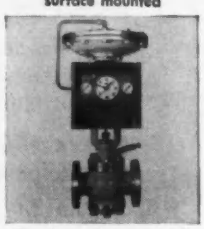
(5) Controls a broad range of variables: Pressures from 30" Hg vacuum to 10,000 psi. Temperatures from —350 F to + 1000 F. Can be adapted to control many other variables, including liquid level.

**Sample price: $126.00 for unit with 316 S.S. Bourdon tube, range 0-600 psi, proportional control 1-100%.*



Typical pressure reducing service

Can be panel or surface mounted



Can be valve mounted

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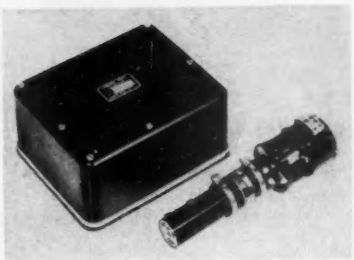
Write for Catalog 310 . . . Gives complete specifications and description of the USG Pilot as well as pneumatic transmitters and receivers for process instrumentation. Send for your copy today, or contact your nearest USG distributor.

UNITED STATES GAUGE
DIVISION OF AMERICAN MACHINE AND METALS, INC., SELLERSVILLE, PA.

USG

NEW PRODUCTS

COMPONENT PARTS



OUTPUT TO 10 WATTS

This compact, completely transistorized servo amplifier provides variable damping or feedback control and a wide range of input impedances. With the input arranged in a summing configuration, it may be used as a differential amplifier. The unit has up to 10 watts output power and is designed to drive a servomotor generator with standard 115/57.5-volt or 40/20-volt control phase without an output transformer.—John Oster Mfg. Co., Racine, Wis.

Circle No. 57 on reply card

RUGGED SYNCHROS

Here's a size 11 synchro designed to take the battering of a missile component. It's corrosion-resistant and has a temperature range from minus 54 to plus 200 deg C, vibration tolerance of 20 g's, shock tolerance of 50 g's.—Kearfott Co., Little Falls, N. J.

Circle No. 58 on reply card

RECTILINEAR POT

The Model 110 precision rectilinear potentiometer features a carbon film resistance element and dust-proof housing. Units are available with single or dual outputs. A patented trimming process permits outputs to

NEW FROM Saginaw

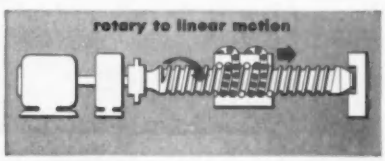
PHOTOGRAPHED ACTUAL SIZE
BALL CIRCLE DIAMETER: only 3/16 inch

SMALLEST ball/bearing SCREW OFFERS BIGGEST ANSWER TO CRITICAL POSITIONING/CONTROL PROBLEMS

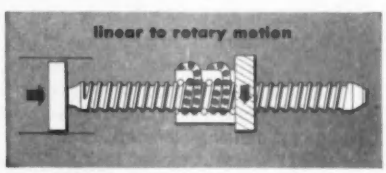
Another timely development by Saginaw . . . for imaginative manufacturers of ultra-precise controls in the electrical and electronic fields. For Saginaw Miniature b/b Screws will solve critical positioning/control problems for radar tuners, missile and rocket guidance and telemetering systems, automatic switch-gears, electronic machinery controls . . . plus a host of other applications.

These amazing little fellows are so compact and weigh so little—you can save greatly on space and weight. So efficient—over 90%—you can use much smaller motors and gear boxes. So precise—you can position components within .0005 inch per inch of travel. (If application requires, lash can be eliminated.) So dependable—you can rely on remarkably long service life even in extremely adverse environments.

Every day Saginaw's experienced engineers are helping more and more forward-looking manufacturers to gain these advantages of Saginaw Miniature b/b Screws. Let them help you plan your application. No obligation. Simply phone, write or mail the convenient coupon below.



NUT TRAVELS: When rotary motion is applied to the screw, the b/b nut glides along the axis of the screw on rolling steel balls, converting rotary force and motion to linear force and motion with 4/5 less torque than acme screws.



SCREW TRAVELS: When rotary motion is applied to the b/b nut, the screw glides along its longitudinal axis on rolling steel balls, converting rotary force and motion to linear force and motion with unprecedented efficiency.

Saginaw

ball bearing Screw

SAGINAW STEERING GEAR DIVISION OF GENERAL MOTORS • SAGINAW, MICHIGAN
WORLD'S LARGEST PRODUCER OF BALL BEARING SCREWS AND SPLINES

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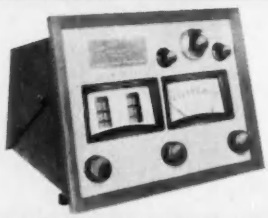
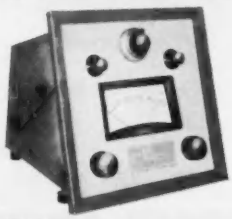
Therma Bridge
THERMAL CONDUCTIVITY EQUIPMENT

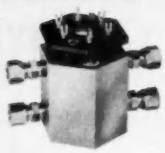
NEW... design concepts

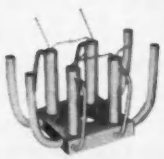




COMPLETE line of instruments and cells

for thermal conductivity measurements





Now . . . a complete line of precision instruments housed in advanced, functionally designed cabinets with latest refinements in circuitry and design.

Advanced design "Therma Bridge" sensing cells, the heart of all gas conductivity measurements are available in two metal mass weights. A heavy-weight, open core, hexagonal cell and light-walled, individual cavity cell. Both cells are available with either hot-wire or thermistor sensing elements.

Instruments include Therma Bridge Gas Analyzer for monitoring purity values in gas streams and for wide applications in gas impurity analysis; Therma Bridge Stabilized Temperature Sensing Unit for use in low impurity percentages in gas analysis and chromatography, as well as for measurements at elevated temperatures; Therma Bridge Power Supply and Control Circuit Unit the power source for all thermal conductivity sensing cells.

All equipment is designed for rack or individual mounting. Special custom design service for special applications. Write today for complete technical details on the full line of Therma Bridge Gas Thermal Conductivity Instruments and Cells to . . .

Industrial Instruments

Industrial Instruments Engineering Corp.

89 Commerce Road, Cedar Grove, Essex County, N. J.

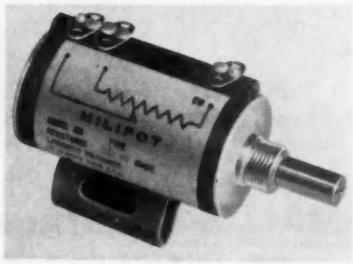
NEW PRODUCTS

follow a linear or nonlinear relationship with shaft motion.

Characteristics:

Linearity: 0.05 percent for 1-in. stroke
Life: 20 million strokes
Temperature range: minus 55 to plus 85 deg C
Power dissipation: 2 watts/in. of stroke
—Computer Instruments Corp., Hempstead, N. Y.

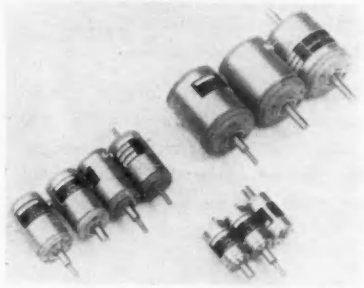
Circle No. 59 on reply card



ALL-METAL CASES

The popular-priced Milipot shown above is available in all-metal cases. This small (1x1.8 in.) precision potentiometer also has stainless-steel shafts, permanently lubricated bearings, precious-metal brushes and slip rings —Voak Engineering Co., Upland, Calif.

Circle No. 60 on reply card



CLUTCHES & BRAKES

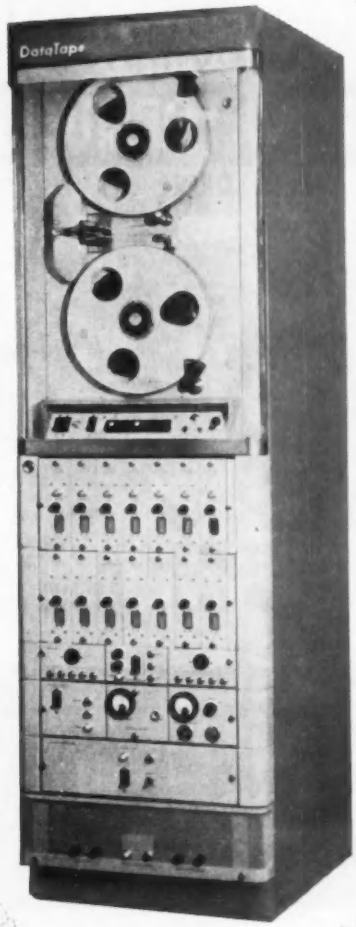
Photo above shows part of a new line of miniature magnetic clutches, brakes, and clutch-brakes. The complete line includes 32 different models in BuOrd frame sizes 8, 11, and 18, featuring both direct and reverse action. Standard operating voltage is 24-28 volts, but other ranges are available. All units meet mil spec E-5272A for environmental conditions.—Fae Instrument Corp., Long Island City, N. Y.

Circle No. 61 on reply card

90%

of all U. S. long-range missile test flights are recorded on CEC **DataTape**

- quickly adaptable to use 1-mil base high-strength Mylar instrumentation Tape *
- meets IRIG specifications
- records and reproduces up to 14 tracks of information
- low flutter . . . even at low tape speeds
- system frequency response from 0 to 100 kc
- interchangeable Analog, PDM, or FM plug-in amplifiers
- uses CEC all-metal-surface magnetic heads
- provisions for remote monitoring



5-752 RECORDER/REPRODUCER

CONTINUOUS LOOP TRANSPORT

DIGITAL MAGNETIC TAPE RECORDER/ REPRODUCER

DATATAPE AIRBORNE SYSTEM

Magnetic Tape Recorder

Power Supply

Record Amplifiers

For complete information on the 5-752, write for Bulletin CEC 1576-X23.

CEC's NEW ADJUSTABLE TAPE LOOP ATTACHMENT permits the standard 5-752 Recorder/Reproducer to be converted quickly and inexpensively into a continuous loop transport for repetitive playback and data analysis. Loop lengths are adjustable from 2 to 20 feet.

* **EXCLUSIVE NEW FEATURE** of the 5-752 now permits the use of 1-mil base Mylar tape and allows 7200 feet of tape to be loaded on a 14-inch reel. Provides 50% more tape footage with radically reduced opportunity for tape breakage.

DataTape Division

Consolidated Electrodynamics

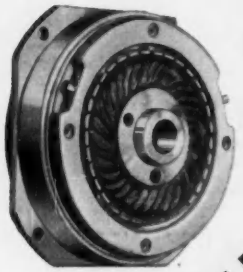
300 North Sierra Madre Villa, Pasadena, California

OFFICES IN PRINCIPAL CITIES THROUGHOUT THE WORLD

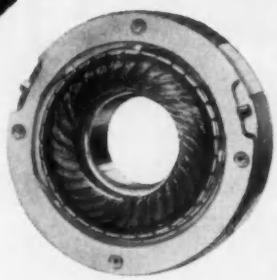
a Complete line of

D. C. TORQUE MOTORS

FOR DIRECT DRIVE SERVO APPLICATIONS



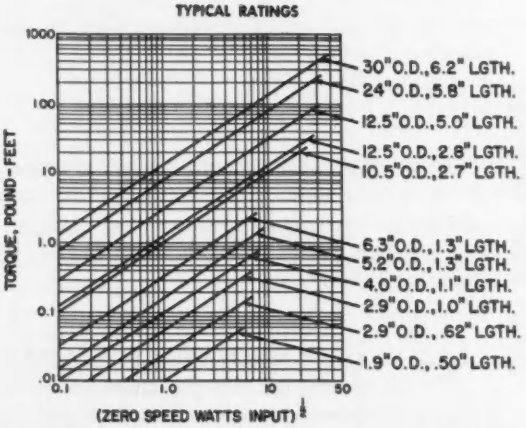
IN TYPICAL HOUSING



WITHOUT HOUSING

- High angular acceleration by utilizing direct drive (4,000 rad./sec.^{2})
- High peak torque per unit volume
- Minimum control and total power input
- Rapid electrical response
- Optimum shape for compact systems

THIS DESIGN TAKES MAXIMUM ADVANTAGE OF THE PROPERTIES OF DC CONTROL POWER AND PERMANENT MAGNET FIELDS.



Matching Rotary Amplifiers Also Available

For further information and Catalog write to:

INLAND MOTOR CORPORATION

MANUFACTURERS OF ELECTRICAL MACHINERY

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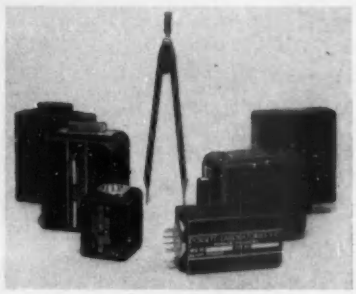
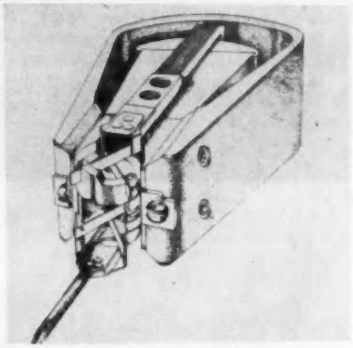
NEW PRODUCTS



VOLTAGE-CONTROLLED

Shown are six new voltage-controlled subcarrier telemetering oscillators. According to the manufacturer, their size, weight, and power requirements are the lowest on the market. Model 0-22, for example, just a little over a 1-in. cube, draws only 25 milliwatts. One volt gives 7½ percent frequency change; input impedance is ½ megohm; and output ranges to several volts on RDB channels.—Dorsett Laboratories, Inc., Norman, Okla.

Circle No. 62 on reply card



GRAVITY-FREE

Developed to lick vibration and acceleration problems in high-performance aircraft instruments, this new moving coil mechanism features a new gravity-compensated, flexure pivot bearing system. Pivot members, arranged in pairs, serve as calibrated springs, provide restoring torque, and cancel out gravity forces for any orientation of the system—Marion Electrical Instrument Co., Manchester, N. H.

Circle No. 63 on reply card

POWER RECTIFIER

The Type 304 silicon power rectifier provides forward direct current up to 12 amp with a maximum peak in-

New RAYTHEON RELIABLE COMPUTER TRANSISTORS switch 1 ampere

H_{FE} controlled at high currents

Temperature range −65°c to +85°c

Type	Punch through Voltage max.	$f_{\alpha b}$ ave. Mc	H_{FE_1} ave. $I_B = 1$ mA $V_{CE} = -0.25$v	H_{FE_2} ave. $I_B = 10$ mA $V_{CE} = -0.35$v	I_{CO} at −12v μA	r_b' $I_C = -1$mA ohms	C_{ob} $V_{CB} = -6$v μμf
2N658	−24	5	50	40	2.5	60	12
2N659	−20	10	70	55	2.5	65	12
2N660	−16	15	90	65	2.5	70	12
2N661	−12	20	120	75	2.5	75	12
2N662	−16	8	25 min.	50	2.5	65	12

Typical values at 25°C unless otherwise indicated

Dissipation Coefficients: In air 0.35°C/mW; Infinite Sink 0.18°C/mW

These new PNP Germanium Computer Transistors made by Raytheon's reliable *fusion-alloy* process add to the already comprehensive line of Raytheon Reliable Computer Transistors which include several in the *Submin* (0.160″ high, 0.130″ dia.) package. Write for Data Sheets.

RAYTHEON SEMICONDUCTOR DIVISION

Silicon and Germanium Diodes and Transistors • Silicon Rectifiers

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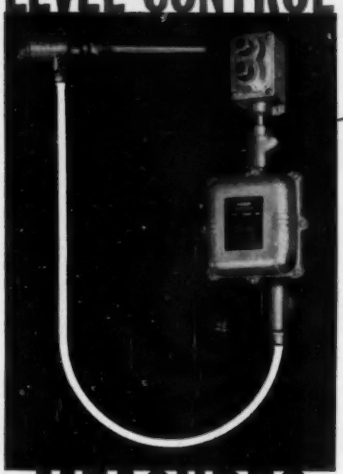
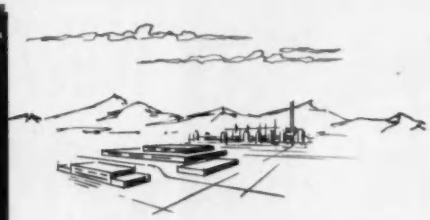
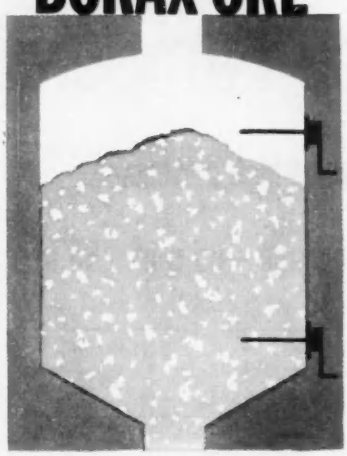
TEKTOR® LEVEL CONTROL





MEASURES GRANULAR SOLIDS LIKE BORAX ORE



At the sprawling U. S. Borax & Chemical Corp. refinery in Boron, Calif. Robertshaw-Fulton Tektor Level Controls keep watchful, automated eyes on the crude borax ore as it moves from the pit bottom into the refinery's giant thickeners, crystallizers and dryers to eventually emerge as derivatives used in heat-resistant glass, gasoline and in rocket fuel research.

Installed as high and low level controls in each of the huge receiving tanks, the R-F Tektors indicate automatically when the ore has reached a predetermined level. A built-in relay-actuated switch operates motor-driven valves and pumps to switch the feed from one tank to another.

Installed more than six months ago, U. S. Borax engineers report the instruments have been operating with extreme accuracy and have required no maintenance.

Thousands of Tektor Level Controls are now in use throughout the world, operating in various liquids, powders, granular and bulky materials and under almost all conditions of temperature, pressure or vacuum. The unit is available in four different types of enclosures including an approved explosion-proof type for hazardous locations. For further information write for Technical Bulletin F-101-4.

Other Tektor applications: Liquids, including water, acids, alkalies, oils and viscous liquids; powdered materials and bulky solids.

AERONAUTICAL AND INSTRUMENT DIVISION

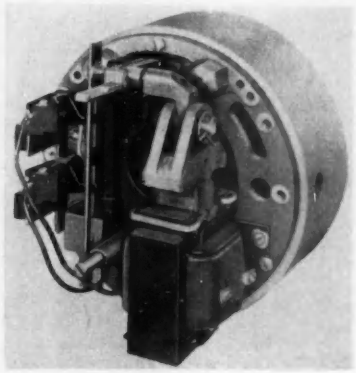
Robertshaw-Fulton CONTROLS COMPANY

SANTA ANA FREEWAY AT EUCLID AVENUE • ANAHEIM, CALIFORNIA

NEW PRODUCTS

verse voltage up to 500 volts. At junction temperatures to 190 deg C, it exhibits no detectable change in its characteristics. Reverse leakage of the cell does not exceed 10 ma at rated peak inverse voltage and maximum temperature. Complete bridge assemblies as well as individual units are available.—Westinghouse Electric Corp., Pittsburgh, Pa.

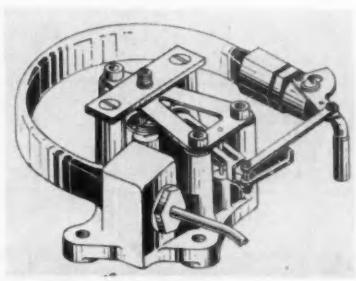
Circle No. 64 on reply card



A DC VERSION

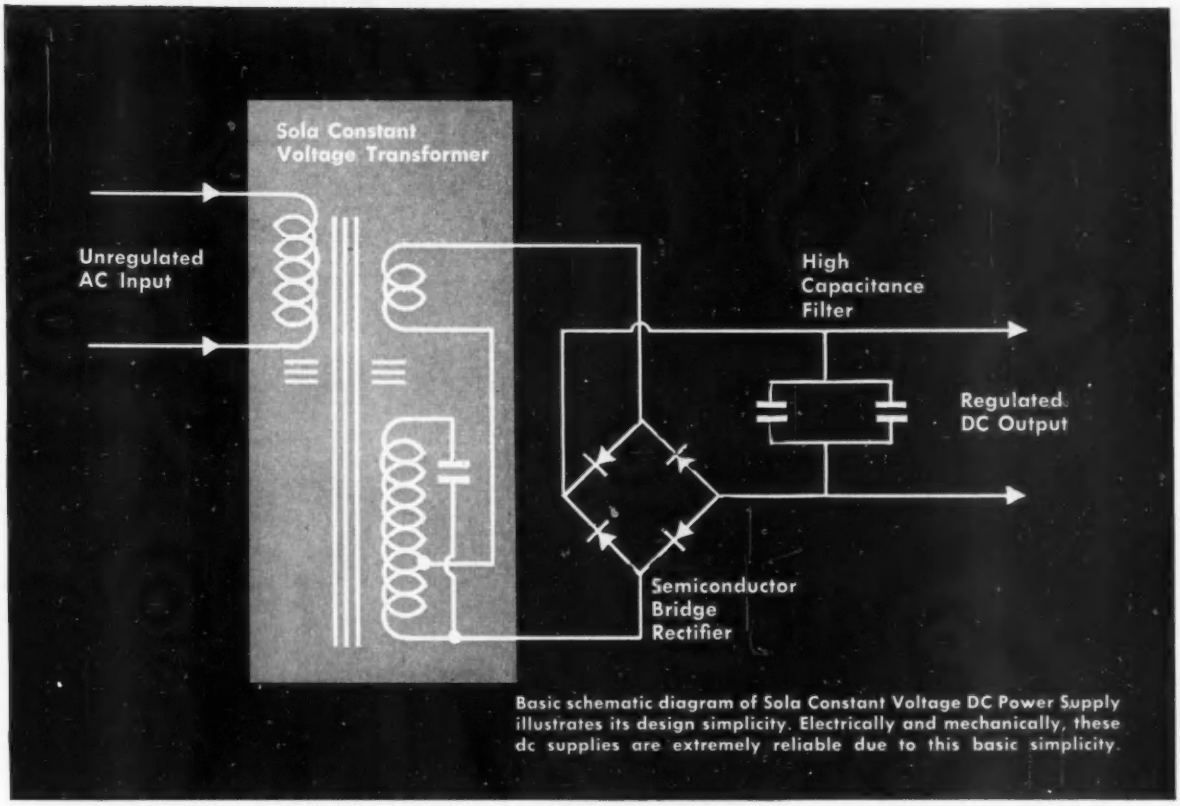
This new shunt-wound brake is the dc version of the company's HT70 Series. Torque ratings range from 10 to 105 lb-ft. Units may be floor mounted, hung on stub-shaft motors, mounted on a double shaft extension, or modified for through-shaft applications. Features include: single solenoid construction, single-point adjustment for lining wear, manual release, and automatic reset.—Stearns Electric Corp., Milwaukee, Wis.

Circle No. 65 on reply card



ELIMINATES THERMAL ERROR

The drawing above illustrates the movement of a new line of precision bourdon tube gages. Chief feature of the movement is a thermal compensating device that corrects for temper-



Basic schematic diagram of Sola Constant Voltage DC Power Supply illustrates its design simplicity. Electrically and mechanically, these dc supplies are extremely reliable due to this basic simplicity.

SIMPLE, regulated DC power supply

Emerson said, "To be simple is to be great," and that perfectly describes the Sola Constant Voltage DC Power Supply. If you want to keep your apparatus as simple as you can (especially if it's basically complicated) this dc supply will do it.

You needn't worry about manual adjustments or maintenance in the field. There are no moving or expendable parts . . . no tubes. The entire supply is a unique combination of three components: 1) A special Sola Constant Voltage Transformer, 2) a semiconductor rectifier, and 3) a high-capacitance filter. It's that simple. It's extremely dependable.

Regulation is ±1% against line voltage variations up to ±10%. Ripple is within 1% rms. Outputs are in the "ampere range." It's particularly well-suited for use on apparatus with pulse, intermittent, or variable loads. Efficiency is high.

The Sola Constant Voltage DC Power Supply is simple, compact, very reliable, and moderately priced.

Fixed output — six ratings available from stock

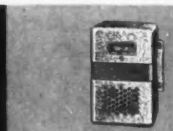
Adjustable output — six ratings from stock

Custom-designed units produced to your specs

Write for Bulletin 26F-DC-235

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in Principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

SOLA

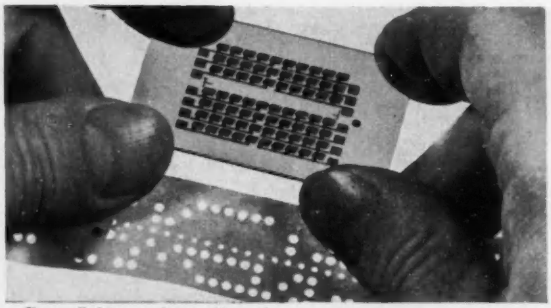


CONSTANT VOLTAGE TRANSFORMERS

REGULATED DC POWER SUPPLIES

MERCURY LAMP TRANSFORMERS

FLUORESCENT LAMP BALLASTS



The small dots are photosensitive resistors connected by gold conductors.

This 70-cell photosensitive resistor "reads" a punched tape . . . What do you want to read?

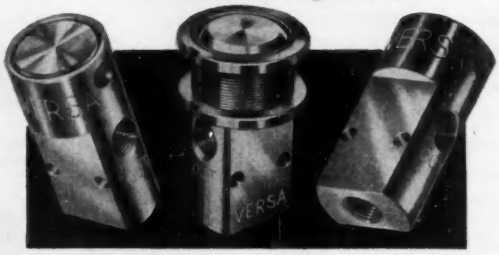
The Kodak Ektron Detector makes possible new techniques for reading punched tapes, cards, code wheels, and the like. The lead sulfide photosensitive elements can be laid down in all sorts of complex and exact arrays and mosaics. Units are characterized by a broad signal response from 0.25 microns in the ultraviolet to 3.5 microns in the infrared, a high signal-to-noise ratio, stability under vibration, and small size. For a booklet giving detailed information on Kodak Ektron Detectors, write Military and Special Products Sales,

EASTMAN KODAK COMPANY
Rochester 4, N. Y.

Kodak

Versa "A" Valves

Give MAXIMUM Capacity In MINIMUM Space...



- Versa solves the space problem with a truly economic valve.
- The overall size of the Versa "A" valve is only 2" high by 1" in diameter, yet it has the capacity of much larger valves.
- Ideal for controlling cylinders, instruments and larger pilot valves.
- Available in ⅛" NPT in 2-way & 3-way types with or without button guard, in either normally open or closed models.
- Simple to mount on equipment or can be furnished for panel mounting.
- Prices range from $4.00 to $6.50 each. For complete information write today for Folder #14S.

VERSA

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ature growth of the linkage members and variations in the modulus of elasticity in the tube itself. Recorded accuracies are on the order of 1 part in 1,000.—Heise Bourdon Tube Co., Newtown, Conn.

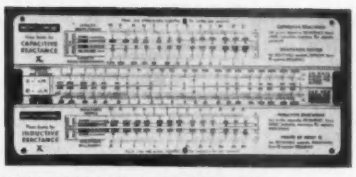
Circle No. 66 on reply card

COMPACT AND ACCURATE

Called the Model SND, this new sum and difference amplifier appears to be well suited for correlating output signals from a variety of transducers (strain gages, hot wire anemometers, sound and vibration pickups). Frequency response of each channel is flat from 1 cps to 100,000 cps; gain is 0.4. The sum is correct to within 2 percent and the output difference signal for identical inputs is down 40 db. Maximum input signal for undistorted output is 40 volts peak to peak.—Flow Corp., Arlington, Mass.

Circle No. 67 on reply card

ACCESSORIES & MATERIALS



REACTANCE SLIDE RULE

A single setting of this new, improved reactance slide rule solves such problems as resonant frequency, capacitive reactance, inductive reactance and coil "Q", and dissipation factor. Applications include the design of filters, tank circuits, transformers,

Miniature plug-in Relay for printed circuits

SQPC Relay—Length, 1 3/4"; height, 1 5/16" to 1 3/4" (depending upon number of springs); width, 1".

...millions of operations without attention!

Need a dependable relay for direct insertion into printed circuits? Automatic Electric's new Printed-Circuit Relays run *up to 120 million operations without a single readjustment or relubrication!*

Miniaturized without sacrifice of ruggedness, these *SQPC* Relays, with reinforced mounting, deliver reliable performance under extreme conditions – dependable contact operation at up to 10.5 G's, 25 G's shock, and temperatures from –55° to +85°C.

SQPC Miniature Printed-Circuit Relays are available with many different contact spring arrangements—can be permanently secured with any acceptable soldering technique.

RELAY SPRING TAKING ITS "PHYSICAL." A technician explores critical spring areas for tool marks and concealed defects—calibrating radii to .001 inch—checking for the strength and stamina which will assure long, uniform service life. Automatic Electric quality control is unmatched in the industry—a compelling reason why you should specify AE in your engineering.

Save parts, assembly and wiring time by using printed circuits—and Automatic Electric SQPC Relays. For full details, write or call: Automatic Electric Sales Corp., Northlake, Illinois. *In Canada:* Automatic Electric Sales (Canada) Ltd., Toronto. *Offices in principal cities.*

AUTOMATIC ELECTRIC ®

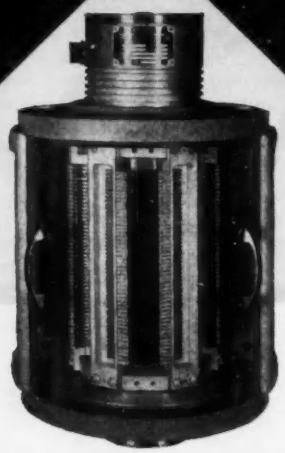
Northlake, Illinois • Subsidiary of **GENERAL TELEPHONE**

Now you can order from stock...

the new

BRYANT MAGNETIC STORAGE DRUM

Unequalled for precision, versatility, and low cost



The new 512A Bryant general purpose magnetic storage drum meets the exacting demands of all permanent storage problems, yet is versatile enough to be used as a laboratory instrument. These 5″ dia. x 12″ long drums are stocked for immediate shipment at a price that is far below the cost of customer-designed drums.

Features: Guaranteed accuracy of drum run-out, .00010″ T.I.R. or less; Integral motor drive; Capacities to 625,000 bits; Speeds up to 12,000 R.P.M.; 500 kilocycle drum operation possible; Accommodates up to 240 magnetic read/record heads; For re-circulating registers as well as general storage.

Special Models: If your storage requirements cannot be handled by standard units, Bryant will assist you in the design and manufacture of custom-made drums. Speeds from 60 to 120,000 R.P.M. can be attained, with frequencies from 20 C.P.S. to 5 M.C. Sizes can range from 2″ to 20″ diameter, with storage up to 6,000,000 bits. Units include Bryant-built integral motors with ball or air bearings. Write for Model 512A booklet, or for special information.

BRYANT GAGE and SPINDLE DIVISION

P. O. Box 620-L, Springfield, Vermont, U. S. A.

DIVISION OF BRYANT CHUCKING GRINDER CO.

NEW PRODUCTS

amplifiers, and coupling circuits. Rule sells for 75 cents–Shure Brothers, Inc., Evanston, Ill.

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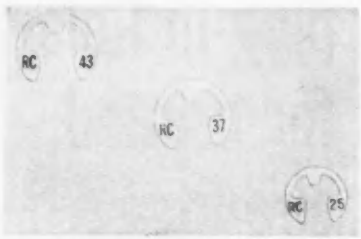
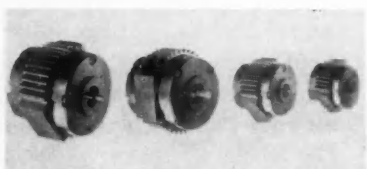


SIZE IDENTIFIED

A brand new line of retaining rings, called Rotor Clips, simplifies positive identification. The size of each ring is clearly engraved on its face. The new rings have a special tapered design that lowers the stress at the midsection.–Rotor Clip Co., Farmingdale, N. Y.

Circle No. 69 on reply card



FINS FOR COOLING

Special cooling fins shown in the photo enable these motors to operate at higher ambient temperatures. Motors shown are ac subfractional hp units. The ribbed aluminum shell are vibration-resistant. – Air-Marine Motors, Amityville, N. Y.

Circle No. 70 on reply card

T'COUPLE CONNECTORS

A new line of plug-in thermocouple components is designed to simplify and speed up connection of thermocouples to industrial instruments. The plugs, jacks, multiple jack panels, and related hardware can be used for either single or multiple connections. Contact inserts are made of compensating materials suitable for use with a variety of thermocouple types. To prevent improperly polarized connections, one contact is slightly larger than the other. – Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.

Circle No. 71 on reply card

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(100) SPECTROPHOTOMETERS. Coleman Instruments, Inc. Bulletin B-240-A, 6 pp. Describes three models of the Coleman Junior Spectrophotometer, each available with one of four power supply arrangements. Also gives details on a variety of cuvettes and cuvette adapters.

(101) OXYGEN INDICATOR. Mine Safety Appliances Co. Bulletin 0817-1, 4 pp. Covers a new portable oxygen indicator. Tells what it is, who can use it, and how it works. Last page lists catalog to the indicator, a variety of sampling lines, and accessories.

(102) PRECISION GLASS. Fischer & Porter Co. Catalog 80-23, 8 pp. Discusses fabrication, materials, tolerances, and applications of precision glass products.

(103) BINDING POSTS. The Superior Electric Co. Bulletin BP958, 4 pp. Shows five ways of using the company's new line of colored binding posts and provides outline dimension drawings. Prices of binding posts and a special hole punch are included.

(104) COMMUTATING & CODING. Consolidated Electrodynamics Corp. Bulletin, 4 pp. Offers a detailed description of the operation and application of the Type 40-101 Plexicoder, a device for commutating and coding signals from as many as 90 transducers at a rate of 112.5 samples per sec.

(105) CONDENSED CATALOG. Energy Control Co., Inc., Special catalog issue of "Energy", 32 pp. A roundup of products manufactured by some 12 companies represented by Energy Control Co. Covers controls for level, flow, temperature, and pressure, as well as gas analysis equipment.

(106) SUBMINIATURE SWITCHES. W. L. Maxson Corp. Bulletin, 4 pp. Illustrates a complete line of Unimax subminiature snap-acting switches of the spdt type. Dimension drawings accompany short descriptions of 17 variations of one basic type. Includes electrical ratings.

(107) FOR REACTOR CONTROLS. Automatic Switch Co. Brochure, 4 pp. Contains general descriptive data on a line of monel and stainless steel solenoid valves for use in nuclear reactor control systems. Types mentioned include stop, spray, relief, and four-way.

(108) LEVEL SENSOR. Robertshaw-Fulton Controls Co. Bulletin RF-581. Details of Betatrol, a new liquid-level sensor that uses beta radiation to sense the presence or absence of a liquid in a vessel. Fields of application include the petroleum, chemical, and food processing industries.

(109) DESKSIDE COMPUTER. Mid-Century Instrumatic Corp. Bulletin, 8 pp. Describes the Model MC-400 Desk-Side Analog Computer, gives full details about its operational amplifiers and other standard and optional equipment. Solution of a typical airframe problem is discussed and illustrated.

(110) CLUTCH-BRAKES. Stearns Electric Corp. Bulletin 504, 8 pp. Engineering data, performance curves, and dimension drawings are used to describe three new miniature clutch-brake combinations.

(111) DEFINES RELAY TERMS. Potter & Brumfield, Inc. Booklet, 16 pp. Contains almost 200 definitions of relay terms as suggested by the National Association of Relay Manufacturers, as well as 21 diagrams illustrating contact arrangements and voltage and current parameters.

(112) SNAP-ACTING SWITCHES.

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W. L. Maxson Corp. Catalog No. 0158, 28 pp. Covers a complete line of precision snap-acting switches, features a convenient pictorial index that tells where to find data on each type. Also has a brief glossary of sensitive-switch terms approved by NEMA.

(113) MOTOR SELECTION. Century Electric Co. Form 270, 12 pp. Tells how to match motor characteristics and load requirements. An application chart provides information on typical driven equipment, character of loads, and starting and running torques.

(114) ON TEMPERATURE CONTROLS. United Electric Controls Co. Condensed Catalog 400, 8 pp. Describes the purposes, capabilities, limitations, applications, special features, and variations of locally mounted and remote bulb temperature controls.

(115) FLEXIBLE ENCODER. Adage, Inc. Bulletin, 4 pp. Describes the Voldicon, a new voltage-to-digital converter capable of 2,000 completely independent conversions per sec. Covers input specifications, outputs, and auxiliary signals.

(116) TRACER CONTROL. General Electric Co. Bulletin GET-2736A, 8 pp. Provides functional description of GE's two-dimension tracer control, featuring technical notes on operation, design, and performance characteristics. Illustrations include photos, line drawings, circuit diagrams, and performance table.

(117) PORTABLE METER. Belleville-Hexem Corp. Bulletin, 4 pp. Contains photographs, specifications, and descriptive material on a new portable, battery-powered multimeter, the Model 110. Also lists important design features, such as low drift input and high overload capacity.

(118) MAGNETIC AMPLIFIERS. Lumen, Inc. 2 data sheets. Describe Models 1058 and 1057 magnetic amplifiers, one a push-pull dc amplifier and the other a push-pull servomotor ac amplifier. Characteristics, technical notes, and a curve showing output voltage vs. control current are included.

(119) MYLAR CAPACITOR. Pyramid Electric Co. Bulletin, 4 pp. Contains engineering data and electrical characteristics on four types of a new nonhygroscopic polyester film capacitor.

(120) PORTABLE VACUUM GAGE. F. J. Stokes Corp. Data Sheet 561, 2 pp. Covers important features of a new portable McLeod-type high vacuum gage. Gage scales for four different models are reproduced actual size and a specification table is included.

(121) METERING SYSTEMS. Milton Roy Co. Data Sheet E-58-2, 2 pp. Illustrates and describes four automatic methods for metering and feeding a precise ratio of odorant to natural gas lines. An all-pneumatic system using controlled volume pumps is described in detail.

(122) GALVANOMETERS. Consolidated Electrodynamics Corp. Bulletin 1528A, 12 pp. Gives complete information on the construction, operation, and application of the company's Series 7-300 precision galvanometers. Curves illustrate frequency response, linearity, phase and damping, and square-wave response.

(123) 10-TURN PRECISION POTS. Beckman/Helipot Corp. Data Sheet 1273, 4 pp. Describes the Model 7603, a 10-turn precision potentiometer for servo mounting. Includes dimension drawings, a table of coil characteristics, a list of tentative specifications, and a discussion of construction features.

(124) PRESSURE GAGES. Kunkle Valve Co. Catalog G-58, 48 pp. Presents a complete line of pressure gages and accessories, with ranges from 15 psi, or 30 in. of vacuum, to 2,000 psi. Offers engineering data and selection tables for a number of industrial applications.

(125) RECORDING OSCILLOGRAPH. Consolidated Electrodynamics Corp. Bulletin 1589, 6 pp. Follows a general description of the Model 5-140 cathode-ray recording oscillograph with detailed discussions of each of its major components.

(126) DIGITAL STRAIN GAGE. Datran Electronics Div. of Mid-Continent Mfg., Inc. 4-page article. Contains some interesting application data on Datran's Resistance Bridge Indicator, an instrument that can be calibrated to indicate directly in microinches of strain, psi, pounds, ft-lb, etc.

(127) MINIATURE FAN DATA. Globe Industries, Inc. Catalog, 14 pp. Provides seven two-page bulletins covering a variety of ac and dc for electronic cooling, ventilating, and exhausting. Both axial and centrifugal types are included.

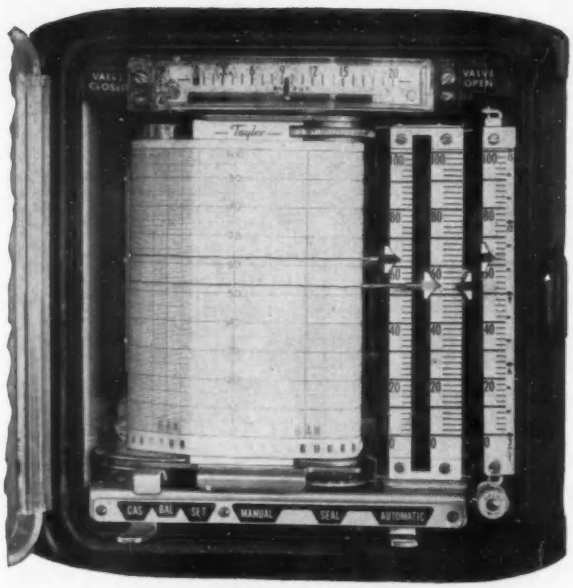
(128) ABSORPTION CELLS. Beckman/Scientific Instruments Div. Bulletin 729, 12 pp. Describes a variety of absorption cells and other sample handling accessories for the Beckman Spectrophotometers. Also lists some special cells with reference path lengths from 1 to 500 mm and volumes from 0.3 to 285 ml.

(129) VELOCITY FLOWMETER. Builders-Providence, Inc. Bulletin 380-K4B, 6 pp. Shows pressure loss and typical accuracy curves for the Propelofio velocity-type flowmeter.

(130) PROPORTIONING PUMPS. Hills-McCanna Co. Catalog No. 604. Covers details and specifications on a full line of proportioning pumps for a variety of metering applications. Capacities range from 6 cc/min to 730 gph or 1,460 gph on units with two feeds.

(131) NEW ENCODER. Fischer & Porter Co. Catalog Sheet 32A100, 2 pp. Describes the manufacturer's Model 32AA2 Digi-Coder, a shaft position to digital converter for transmitting data to an electric typewriter, tape punch, computer, or other equipment.

Complete Cascade System in ½ Normal Space ...Costs Substantially Reduced



Taylor's New TRANSCOPE Plug-in Recorder provides a complete Cascade System . . . in half the space required by other systems*

Never before has a complete cascade system been available in one recorder case in a 6" panel cut-out.

Complete Cascade System. All switches in one case. Operator performs all start-up and shut-down operations in one recorder. No external switches or relays. No extra space needed. Cascade set point always in view.

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Unique, New Bumpless Transfer. New switching system lets you change from *control by secondary* to *control by master,* precisely matching the master output to the secondary control point without comparing gages.

Front of Panel Control Settings let you make adjustments easier, quicker and better! You can clearly see what you are doing, and the results, because the record is continuous.

Stays on Automatic Control while the recorder is removed. There's no need to shut down the process for instrument service or adjustments.

Substantial Cost Reduction. You save substantially since you need only one case, one chart drive, one panel cut-out, one set point transmitter.

* * *

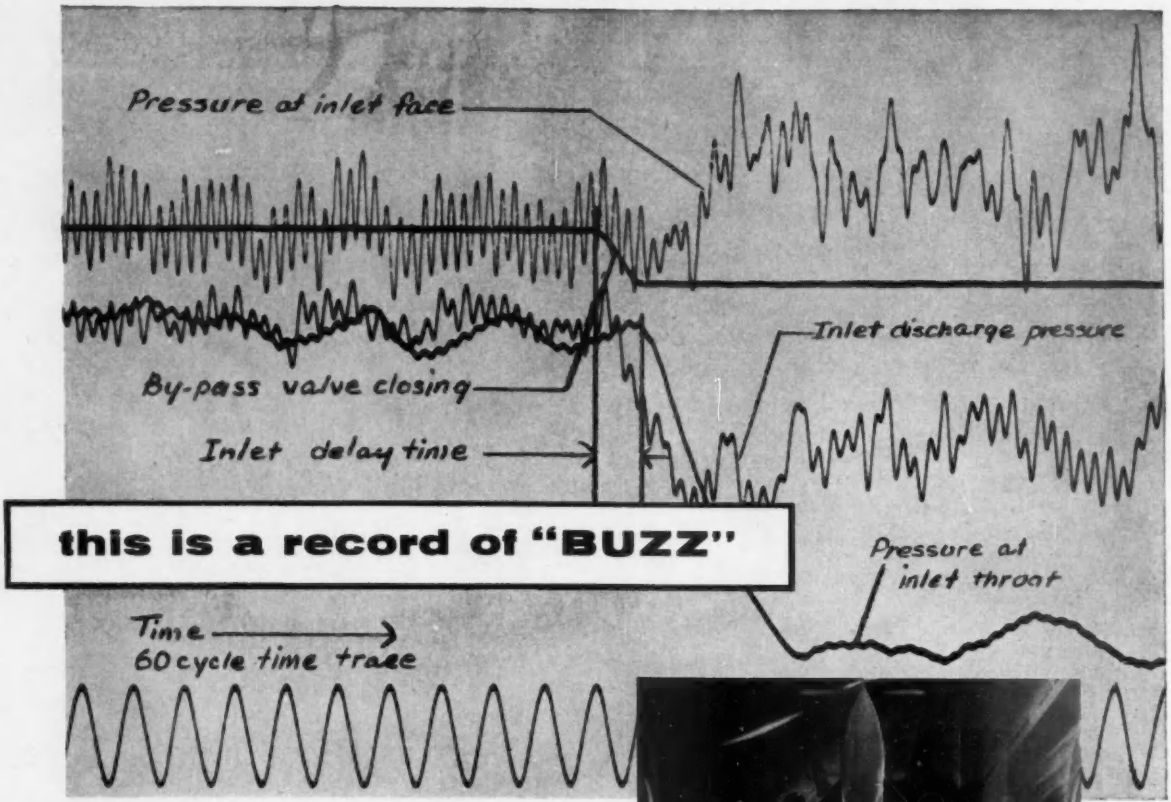
For further information about this revolutionary new Recorder, see your Taylor Field Engineer, or write for **Bulletin 98286.** Taylor Instrument Companies, Rochester, N.Y., Toronto, Ontario.

*Trade-Mark

CASE MATES!

The Taylor TRANSCOPE Controller and Recorder are companion plug-in instruments. Together they give new standards of process control performance... unprecedented stability, accuracy and adaptability. Especially suited for the short spans of measurement encountered in present day processing. The TRANSCOPE Controller is insensitive to ambient temperatures, and highly resistant to mechanical shock. Write for **Bulletin 98278.**

Taylor Instruments MEAN ACCURACY FIRST

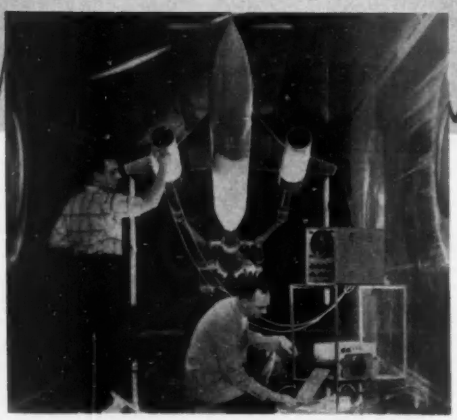


The Visicorder charts pressure fluctuations in a supersonic inlet

A Model 906 Honeywell Visicorder wrote this record of pressure fluctuations . . . "buzz" . . . for the National Advisory Committee for Aeronautics at the Lewis Flight Propulsion Laboratory in Cleveland. Buzz is the term used to describe unsteady variation in pressure and airflow characteristics of a supersonic aircraft or missile inlet.

The purpose of these Visicorder studies is to define the buzz-free operating limits of the inlet, and to provide the designer with structural load information in case the inlet is inadvertently caused to operate on buzz during flight. This is particularly important because inlet buzz can result in fluctuating structural loads of the order of 1000 psf. Depending on the inlet design, this could cause structural failure of the inlet and loss of the airplane.

High response pressure transducers are used to measure these fluctuating pressures and the resulting electrical signal is fed into the Visicorder. Records such as this are also necessary in the determination of the inlet dynamics such as delay time. This information is then used to design inlet control systems.



The HONEYWELL VISICORDER is the first high-frequency, high-sensitivity direct recording oscillograph. In laboratories and in the field everywhere, instantly-readable Visicorder records are pointing the way to new advances in product design, rocketry, computing, control, nucleonics . . . in any field where high speed variables are under study.

To record high frequency variables—and monitor them as they are recorded—use the Visicorder Oscillograph. Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

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Reference Data: Write for Visicorder Bulletin

Minneapolis-Honeywell Regulator Co., Industrial Products Group, Heiland Division, 5200 E. Evans Ave., Denver 22, Colorado

Are You Preparing *Now* For The Next Boom?

America's leading companies are not sitting on their hands waiting for the recession to end. They are planning ahead *now* for higher sales and near-capacity rates of operation.

These facts stand out clearly from the eleventh annual survey of Business' Plans for New Plants and Equipment just completed by the McGraw-Hill Department of Economics:

- **Manufacturing companies expect their sales to increase 20%, on the average, from 1958 to 1961.** Growth industries, such as chemicals and electrical machinery, expect gains of 25% to 34%.
- **If these sales gains are achieved, the average rate of operations in manufacturing will rise from 78% at the end of 1957 to almost 85% by 1961.** This is the point at which pressure on costs begins to mount, as less efficient facilities are pressed into service.
- **Industry is not waiting for this point to begin getting its plants and equipment in shape for the next boom.** Despite record expansion in the past several years, many manufacturing companies plan to add new capacity in each of the next four years. But, more important, they are going ahead with the vital job of modernization and cost-cutting.

In the years immediately ahead almost two-thirds of capital investment will go for modernization and replacement of present plants and equipment. In this way manufacturing companies can avoid the higher costs and the squeeze on profits that occur when producing facilities are not in shape to handle an increase in sales volume.

These are the plans, as reported to McGraw-Hill, of a wide sample of manufacturing companies—for the most part, large firms and leaders in their respective industries. Altogether, these firms account for almost 40% of all employment in manufacturing industries.

Now Is The Time

How do your plans measure up? Are you planning ahead now for a 20% sales increase in the next three years? Is your company planning to modernize its buildings and equipment more rapidly than at any time in the recent past? If not, here are some of the inducements

that McGraw-Hill editors report from their continuous checking on the state of business.

(1) **There are plenty of opportunities for increasing efficiency by the installation of new equipment and the improvement of layouts in plants, warehouses and offices.** Despite the installation of tremendous volumes of metalworking equipment in recent years, according to AMERICAN MACHINIST over half of the machine tools now in U. S. factories are over 10 years old. Replacement of worn-out and obsolete equipment will mean material savings in operating and maintenance costs.

(2) **Machinery, parts, materials and labor are much more readily available now than they are when the economy is running at full steam.** You can be more particular about quality and about specification to meet your own requirements.

(3) **With lower interest rates and less competition for loans, it is both easier and cheaper to borrow money to finance equipment and construction.** To wait for another boom is to run the risk of having to pay higher interest rates and look harder for money.

(4) **Although there is an adequate supply of most types of labor available now, the prospec is that the supply of factory labor over the years ahead will be tight.** In 1965, there will actually be fewer men and women between the ages of 25 and 44 than there are now. Good factory workers will be either hard to get, or wage rates will rise sharply or—more likely—both. The best answer is to anticipate the rise in labor costs by installing more efficient equipment to increase labor productivity.

(5) **Finally, the costs of investing in new buildings and improved equipment *now* are almost surely less than they will be later.**

These are some of the reasons why many leading firms find ***now*** the best time in years to start on a program of plant modernization. There are other good reasons in the many new products and processes coming from the boom in research and development. This year industry will spend over $8 billion on R & D—$1 billion more than in 1957. And a heavy share of the new product development will consist of better machines and processes to be made available during the next few years. Already the pace of technical advance is so rapid as to call for modernization of plants built only a few years ago.

Years of Opportunity

It has been said that the years between now and 1961 are the "middle years" between two booms. This does not mean a long period of recession, but a period of slower growth—a transition from the postwar boom based on deferred demand, to a new boom in the 1960s based on dynamic population growth and a revolution in technology.

If so, these are the years of opportunity for business—opportunity to prepare for the growth that lies ahead with the most efficient equipment, the most modern plant and the best production organization that can be devised. This is the way to fight higher costs and avert a resumption of inflation. This is also the way to ensure that your company will be ready for its new markets in the 1960s.

Are you planning ahead ***now*** to be among the leaders?

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ABSTRACTS

Solid-state Devices Improve Servo Performance

From "Application of Switching Transistors and Saturable Reactors in a High-Performance Servo" by F. B. Cox Jr. and P. R. Johannessen, both of MIT. AIEE Paper No. CP 58-89, presented at the AIEE Winter General Meeting, New York, Feb. 2-7, 1958.

This paper shows how servo performance can be improved by magnetic devices and transistors performing as amplifiers, modulators, and demodulators. Substitution of solid-state devices for electronic amplifiers and mechanical choppers not only increases efficiency, reliability, and durability, but minimizes size and weight.

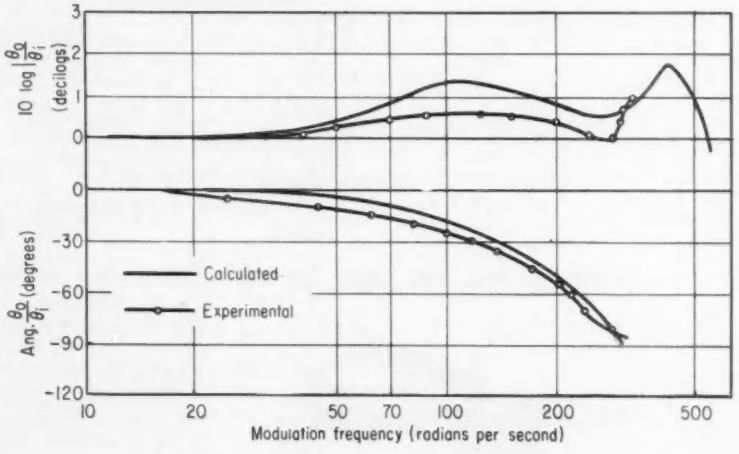
The drift and slow response of conventional 60- and 400-cycle magnetic amplifiers limit their applications. For example, the drift problems encountered in cascading two magnetic amplifier stages make an electronic preamplifier mandatory for adequate gain. However, a high-frequency supply voltage can overcome many of these inherent limitations.

The high-performance position servo analyzed in this paper was designed with no particular application in mind, but every effort was made to determine its maximum bandwidth and velocity constant. Other desirable characteristics, such as negligible drift, short settling time, high efficiency, etc., followed from the inherent properties of the system components.

The servo amplifier consisted of a two-stage transistor voltage amplifier, a magnetic amplifier, and a push-pull switched-transistor power amplifier, the transistor amplifiers being needed to produce the desired loop gain. The magnetic amplifier, supplied from a 5-kc square-wave oscillator, furnished the power transistors with current pulses proportional to the control signal. By controlling the polarity of the transistor bases with respect to ground, these pulses controlled the flow of current to the load. The fact that current flows in the transistors only when an error signal appears in the loop not only enhances the efficiency of the power stage, but minimizes heating in the motor windings.

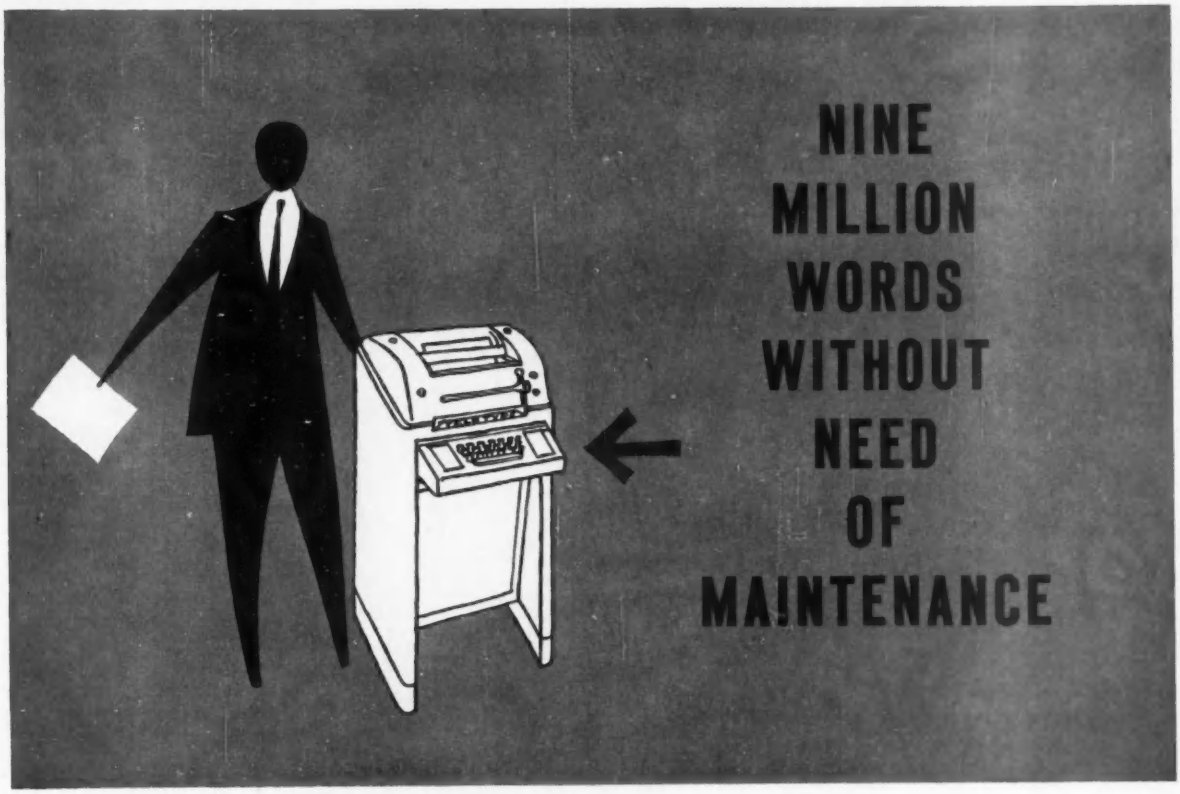
Minor-loop feedback from an ac tachometer produced the desired bandwidth. For constant motor speeds, the tachometer was effectively decoupled from the system by a high-pass filter. Use of a keyed, phase-sensitive, magnetic demodulator eliminated the need for a band-pass filter.

Results of performance tests can be summarized as follows: velocity constant—approximately 9,500 sec^{-1}; torque constant—0.17 oz-in. per millirad, referred to the motor shaft; open-loop gain crossover frequency—230 rad per sec; settling time for a 1-deg step input—approximately 20 millisec, again referred to the motor shaft.



The curves above show the closed-loop sinusoidal frequency response of the system for an input signal corresponding to a 1-deg peak displacement at the motor shaft. Equipment limitations prevented the determination of resonant frequency and peak magnitude ratio.

Following their summary of system performance, the authors describe characteristics of the major system



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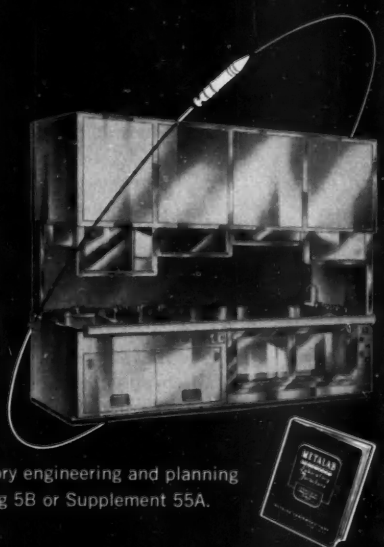

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ABSTRACTS

components. Three forms of compensation are discussed and reasons presented for the ultimate choice of tachometer feedback. A mathematical analysis of the overall system concludes the paper.

Versatile Mass Flowmeter

From "Gyro Integrating Mass Flowmeter" by L. T. Akeley, L. A. Batchelder, and D. S. Cleveland, all of GE. ASME Paper No. 58-IRD-3, presented at the Fourth Annual Conference, Instruments & Regulators Div. of the ASME, University of Delaware, Newark, Del., April 2-4, 1958.

The mass flowmeter, unlike the orifice and other volume-measuring meters, requires no temperature, pressure, or specific-gravity correction, and will accurately measure the mass flow of a fluid having a mixed or changing phase. It may be calibrated with one fluid and measure another.

The particular instrument described in this paper, an integrating-type mass flowmeter, provides a direct digital indication of total fluid flow in pounds. It uses standard momentum-principle elements (described previously by other authors) plus a three-axis gyroscope which precesses at a rate proportional to mass flow. The precession axis of the gyro is geared to a direct-reading cyclometer register and to electrical contacts whose pulse rate is also proportional to mass flow. The contracts permit remote indication, integration, or both.

A brief mathematical analysis shows that meter output is in mass units, and is quite independent of power supply voltage and frequency. However, in using the three-axis gyro as a transducer of torque to angular velocity, it is important that the gyro be maintained level within a relatively small angle of tilt. "Level" here means the condition where the major and spin axes are orthogonal. For negligible error, tilt should be within 1 or 2 deg.

Because it was designed primarily for metering high-pressure natural gas, the instrument had to have an accuracy within 1 percent over 30 to 100 percent of its flow rating, and had to be explosion-proof for indoor and outdoor use at pressures up to 2,000 psi.

Performance tests were not able to indicate whether these requirements were met, because an inferential-type

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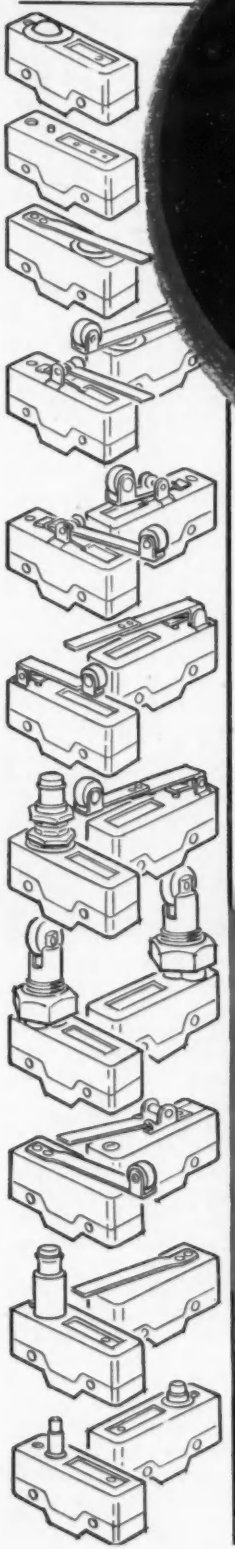

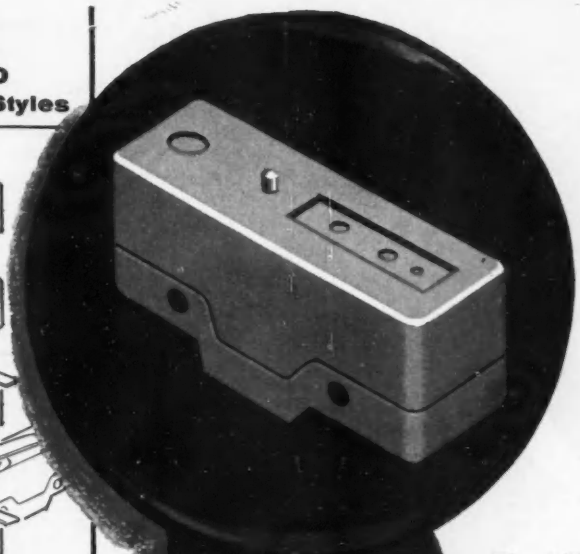

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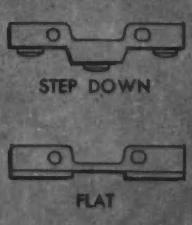

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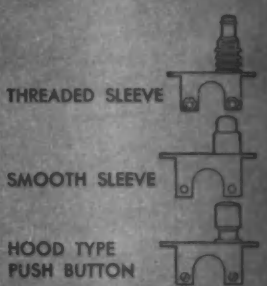

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Design and Manufacture of Electro-Mechanical Timing Devices

ABSTRACTS

orifice meter was used to measure the mass flow. Fortunately, however, a system is now being built that will weigh several thousand pounds of a flowing fluid with an accuracy of better than 99.95 percent. This will provide the needed gas-flow standard for checking high-accuracy integrating mass flowmeters.

Flowmeter Problem

From "Analysis of the Effect of Pulsations on the Response of Mercurial-Type Differential-Pressure Recorders" by R. J. Martin and D. S. Moseley, both of the Southwest Research Institute. ASME Paper No. 57-A-82, contributed by the Committee on Fluid Meters for presentation at the Annual ASME Meeting, New York, Dec. 1-6, 1957.

When a mercury-type differential-pressure recorder is used to measure gas flow, pressure pulsations in the gas stream can cause appreciable errors in the actual recording. If this pulse frequency is near the resonant frequency of some element in the meter, and the chart speed is slow, an effect known as "painting" results. The record appears not as a single line but as a broad inked band.

To guide instrument designers, the authors undertake an analysis of the frequency response of the principle elements in this type of recorder. Lead lines, mercury column, float, and pen are analyzed with respect to pen displacement as a function of harmonic pressure disturbances at the pressure taps. After linearization of equations, three basic resonances are found. The lowest of these, the mercury column resonance, can be removed by overdamping, according to present practice. The second is a float-on-mercury resonance, which can be controlled in frequency. For example, reducing the mass of the float sufficiently shifts the resonant frequency to some value above the range of probable disturbances. Finally, lead-line resonance can be frequently controlled by reducing the length of lines used.

The authors account for certain nonlinearities in the system, but these are not included in the computations. The analysis assumes that the amplitudes of disturbance are small enough, or can be made small enough in practice to permit linearization of the equations. Actually, in the amplitude range, where these linearized equations would not suffice, this type of meter would not be used. Thus, for practical

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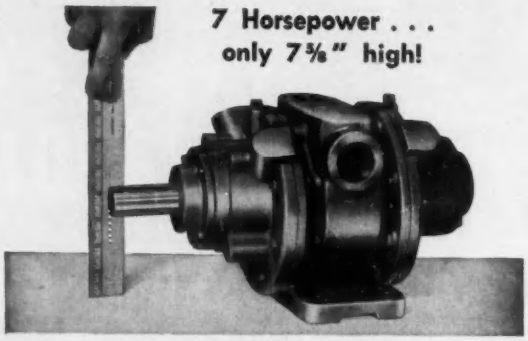

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ABSTRACTS

purposes, the linearized equations are adequate.

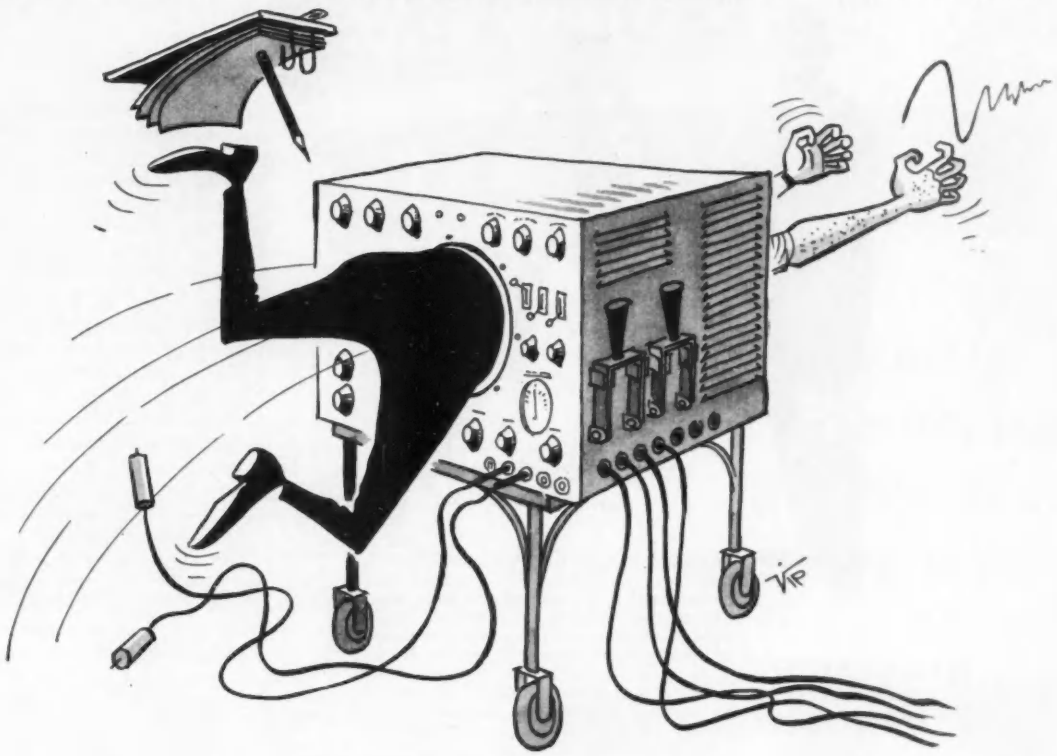
High Accuracy Encoder

From "A High Precision Digital Shaft Position Indicator" by Donald H. Raudenbush, Telecomputing Corp. Paper No. 46.6, presented at the IRE National Convention, New York, March 24-27, 1958.

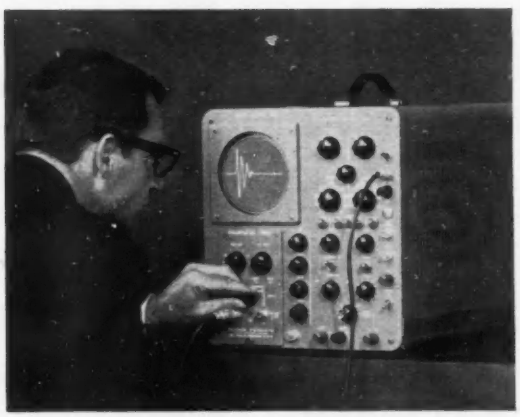
Subject of this paper is a unique system for the digital indication of a shaft position with an error of less than 6 seconds of arc. The transducer, mounted on the shaft whose position is desired, consists of two resolvers. These put out ac signals at phase angles proportional to shaft position. The phase angular output of one resolver determines shaft position to a precision of one part in 200, while the output of the other yields a resolution of only one part in 200,000. The two outputs, therefore, are identified respectively as course and fine. The physical configuration of the transducer requires that ac signals of two different frequencies excite the resolvers. Since the transducer output appears as a composite signal on a single line, electronic filters are used to recover the separate components.

Harmonic generation expands the phase angular information by factors of 10 and 100 to gain the higher resolution. Digital conversion of the resulting expanded phase angle for each of the five decimal places is performed by a novel cathode ray tube having a visual display in the form of a fluorescent number and ten electrical outputs, only one of which is energized at a time. The electrical output may be recorded on tape or punched cards, or fed directly to a computer or electric typewriter.

The paper goes on to describe the adaptation of this system to an Askania Cinetheodolite range at Edwards Air Force Base. In this application, the system eliminates the manual reading and transcription of elevation and azimuth data on each frame of a film. Two transducers are used, one for the elevation axis and one for the azimuth axis. Their outputs, after suitable expansion, are recorded on magnetic tape at the instrument site. On playback at a central data reduction facility, the phase angle information contained in the reproduced signals is digitized by the converters. This decimal digital data is then encoded to a binary-coded-decimal form for subsequent computer input.



PROBLEM: How to Capture Elusive Transients



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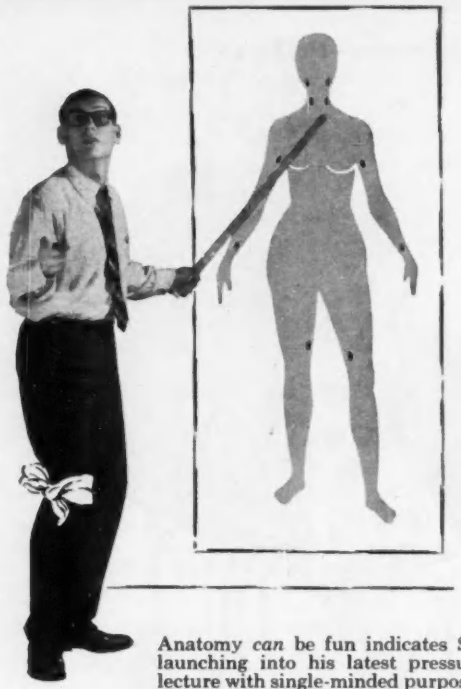

pressure measure

Anatomy *can* be fun indicates Sherman, launching into his latest pressure point lecture with single-minded purposefulness. Sherm's approach is considerably less enlightening than our more academic means of measuring pressure. Example: Rocketdyne, a division of North American Aviation, Inc., applauds (quietly) its success in measuring rocket combustion chamber pressure with BJ Electronics' Single Point Data Processing System.

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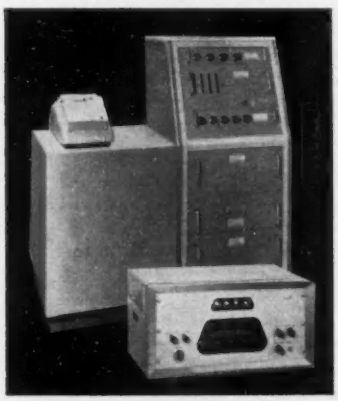

Upper: Rocketdyne System.
Lower Right: New D311 Single Point Data Processing System.

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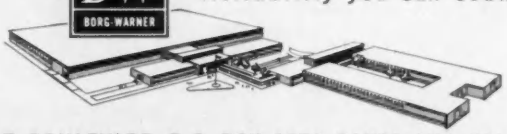

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Important Links

NOTES ON ANALOG-DIGITAL CONVERSION TECHNIQUES. *Edited by Alfred K. Susskind and prepared by staff members of the MIT Servomechanisms Laboratory. 410 pp. Published jointly by The Technology Press of MIT and John Wiley & Sons, Inc., New York, 1958. $10.*

The outgrowth of a special program at MIT last summer on analog-digital conversion techniques, this book offers a detailed exposition of both theory and design. Throughout, the authors stress fundamental concepts and, where possible, express these concepts in quantitative terms. Inherent engineering limitations are considered and relative merits of various approaches weighed.

Subject matter is divided into three parts. The first pertains to systems aspects of digital information processing that influence the specifications for analog-to-digital and digital-to-analog conversion devices. In the second part, a detailed engineering analysis and evaluation of a variety of conversion devices is presented. The third part covers a case study based on development work done at the Servomechanisms Lab of the MIT Dept. of Electrical Engineering.

British Report on Us

AUTOMATION IN NORTH AMERICA. *S. B. Bailey. Overseas Technical Report No. 3, Dept. of Scientific & Industrial Research. 66 pp. Published by Her Majesty's Stationery Office. Available in the U. S. from the British Information Services, 45 Rockefeller Plaza, New York 20, N. Y. 72 cents plus postage.*

Author Bailey, a staff engineer for the Dept. of Scientific & Industrial Research, spent six months in the United States and Canada during the winter of 1955-56. While here, he visited factories, universities, and research establishments to determine the extent to which automation has been developed and practiced. In this book he reports what he found. Though it is written primarily for the benefit of British engineers, it looks like worthwhile reading for many of our own. Certainly few of us ever have the opportunity to make such an extensive tour.

The book opens with a 10-page general survey, which is more or less a summary of the individual reports that follow. The first of these reports

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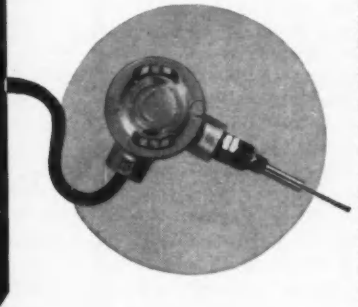

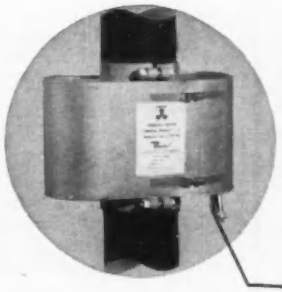

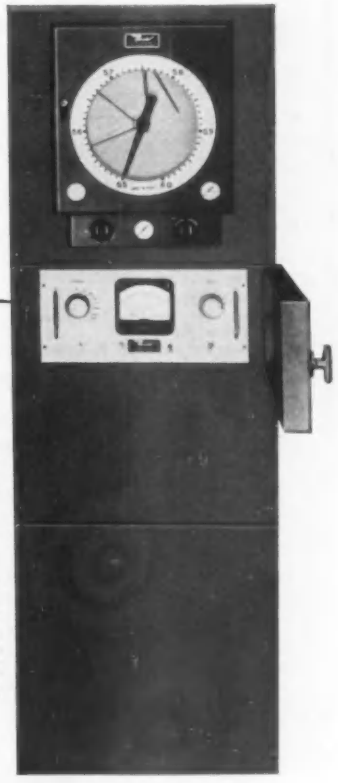

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An important new book from The Technology Press of M.I.T., developed from the 1957 M.I.T. Special Summer Program on Analog-Digital Conversion Techniques. It provides invaluable background material for both the practicing engineer and those without previous experience in the field. Coverage includes: an introduction to the theory of sampling, quantizing, and coding; detailed analysis and evaluation of basic coding and decoding methods for electrical and mechanical analog quantities; and a case study showing how basic principles were applied in a digital flight-test instrumentation system.

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A Text and a Reference

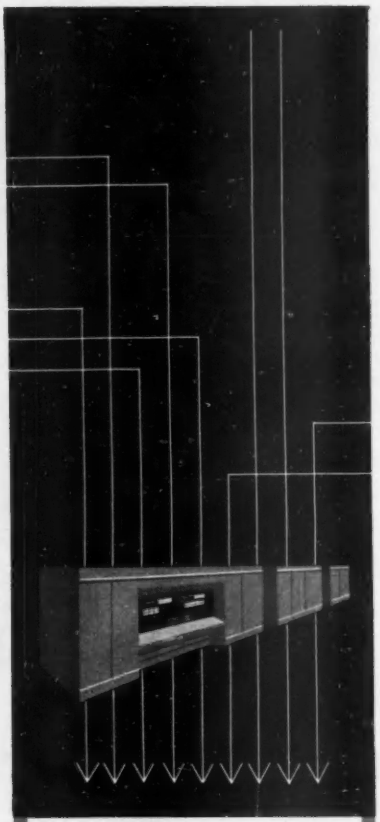
NONLINEAR CONTROL SYSTEMS. *Robert L. Cosgriff, Assistant Professor of Electrical Engineering, Ohio State University. 328 pp. Published by McGraw-Hill Book Co., Inc., New York, 1958. $9.*

Written with both the student and practicing engineer in mind, this new text is one of the first to concentrate on the nonlinear aspects of control systems. Because all control systems are nonlinear in nature, the contents of the book provide the reader with a valuable insight and tools for the analysis and design of such systems.

The author appears to have done a very good job of screening material. Only those methods and techniques which are practical from an engineering standpoint have been included. All mathematics beyond calculus is carefully developed.

The first three chapters introduce the conventional linear theory of control systems, but less emphasis is placed on this than on nonlinear theory and nonlinear limitations. Typical examples illustrate all important points and a set of practical problems (with answers), is presented at the end of each chapter. The author has arranged material so that it proceeds from the simple to the complex, and uses throughout the book the concepts and terminology of automatic-control theory rather than those of classical nonlinear mechanics. Since Laplace transform techniques have little application to nonlinear control, they are reserved for near the end of the book, where transform methods are required.

Some of the recent advances covered include: the use of linear techniques for systems with time-varying parameters to determine systems response; the use of random input signals to excite nonlinear systems; and the application of switching circuits in control systems. Also described are: determination of sys-



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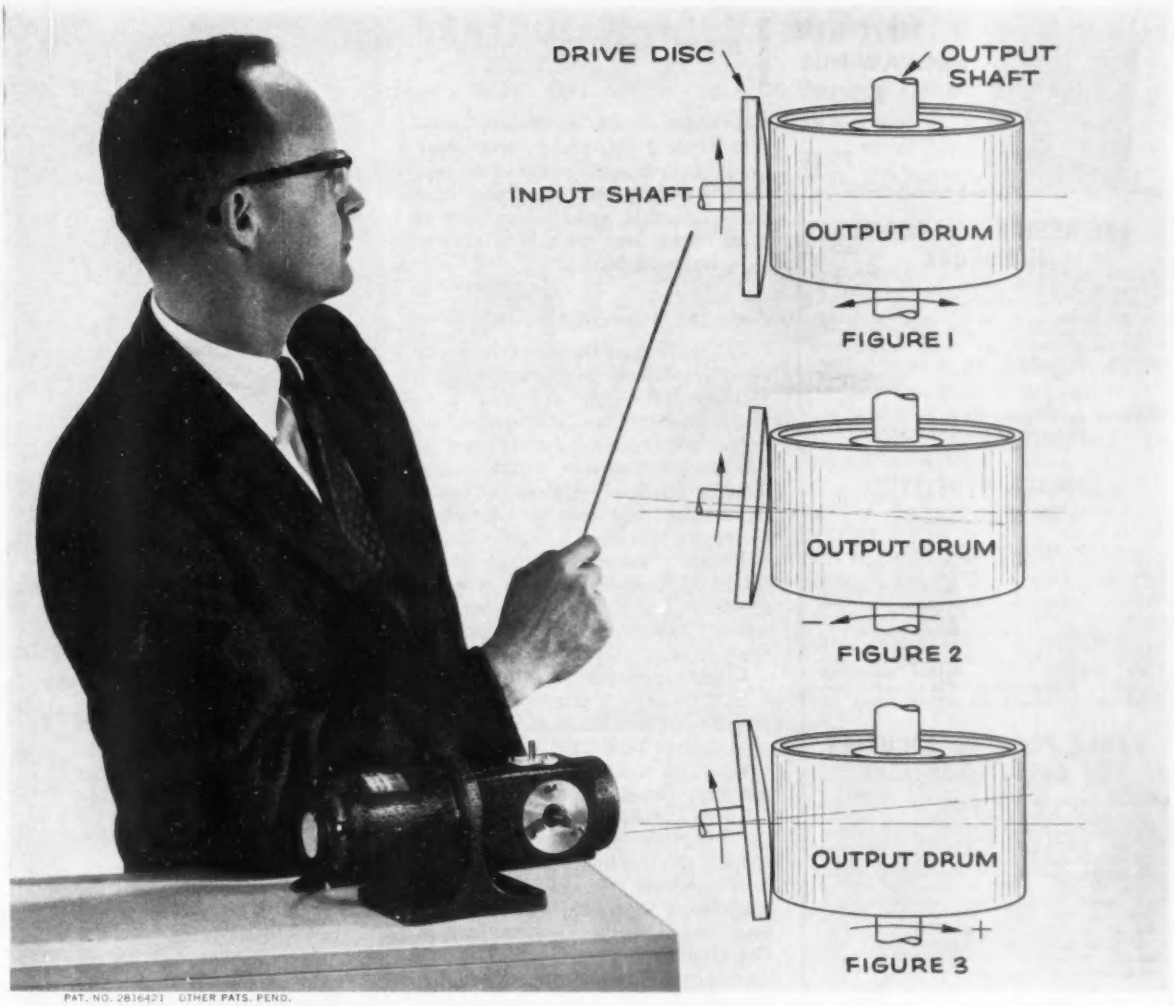

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tem response for generalized input signals using the phase plane representation; sinusoidal response of nonlinear systems; and describing functions (effective gain). Very few of these topics have ever been covered in a textbook before.

Aids for Translating Russian

In recent years there has developed a growing interest in Russian scientific writings and efforts are now being made, both by the Government and by private organizations, to step up translations. But there is still no outstanding Russian-English dictionary on the market. And with science making spectacular advances in every field, it is extremely difficult to compile an up-to-date glossary of technical terms in any language. Following are brief reviews of two recent efforts to improve the picture.

RUSSIAN-ENGLISH GLOSSARY OF ELECTRONICS & PHYSICS. 343 *pp. Published by Consultants Bureau, Inc., New York City,* 1957. $10.

This book contains over 22,000 Russian terms found in the following Russian publications: *Automation & Remote Control, Journal of Technical Physics, Electricity, Radio Engineering & Electronics, Proceedings of the Academy of Sciences, Journal of Acoustics,* and *Communications Journal.* Unfortunately, many useful words have been overlooked, there are a number of incorrect translations, and in many places, the Russian print is very difficult to read. On the other hand, there is a useful 10-page appendix on vacuum-tube equivalents, unit equivalents, circuit notations, and abbreviations. According to present plans, this glossary will become part of a comprehensive Russian-English physics dictionary slated for publication in 1959. Perhaps by that time adequate revisions will have been made.

ENGLISH-RUSSIAN, RUSSIAN-ENGLISH ELECTRONICS DICTIONARY. 943 *pp. Published by the Dept. of the Army, TM* 30-545, 1956. $3.50.

Well-printed, this handy dictionary contains over 20,000 Russian terms and abbreviations, many of which were obtained from Soviet factories, research institutions, and individual scientists. The book covers antennas and waveguides, atomics, aeronautical applications, computers, electro-acoustics, communications, navigation, radar, radiology, automatic control, semiconductors, optics, pulse work, signaling, and many other areas.

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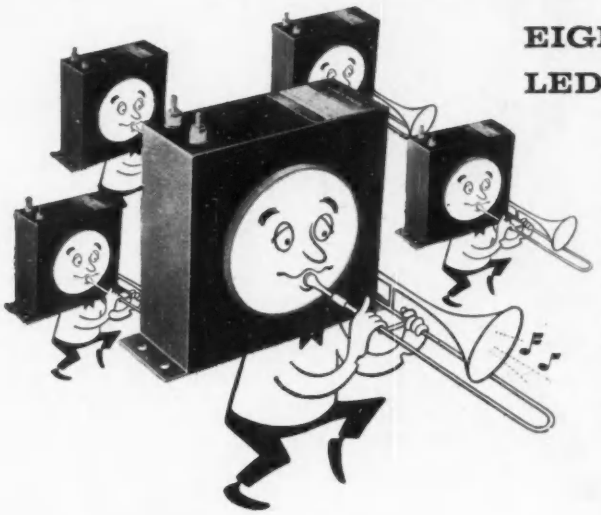

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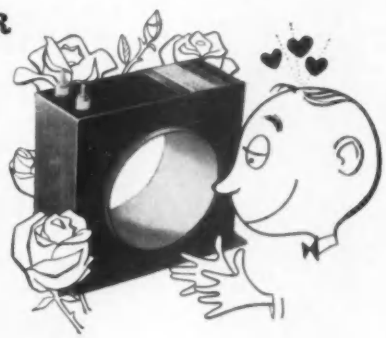

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Automation and Computer Conference, University of Texas, Austin, Tex. June 2-4

Canadian Computer Conference, University of Toronto, Toronto, Canada June 9-10

American Society of Mechanical Engineers, National Conference on Materials Handling, Public Auditorium, Cleveland, O. June 9-12

Fourth International Automation Exposition, and Military Automation Exposition, New York Coliseum, New York June 9-13

Association for Computing Machinery, 13th National Meeting, University of Illinois, Urbana, Ill. June 11-13

American Institute of Electrical Engineers, Ninth National Conference and Convention, Hotel Statler, Los Angeles, Calif. June 12-14

American Society of Mechanical Engineers, Semiannual Meeting, Statler Hotel, Detroit, Mich. June 15-19

Institute of Radio Engineers, Second National Conference on Military Electronics, Sheraton-Park Hotel, Washington, D. C. June 16-18

American Institute of Chemical Engineers, 50th Anniv. Mtg., Process Control Sessions, Bellevue-Stratford Hotel, Philadelphia. June 22-27

JULY

1958 Gordon Research Conference on Instrumentation, Colby Junior College, New London, N. H. July 28-Aug. 1

AUGUST

American Institute of Electrical Engineers, 1958 Special Technical Conference on Nonlinear Magnetics and Magnetic Amplifiers, Hotel Statler, Los Angeles, Calif. Aug. 6-8

American Institute of Electrical Engineers, Pacific General Meeting, Sacramento, Calif. Aug. 19-22

SEPTEMBER

Instrument Society of America, Instrument-Automation Conference & Exhibit, Convention Hall, Philadelphia, Pa. Sept. 15-19

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What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controllers for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability,

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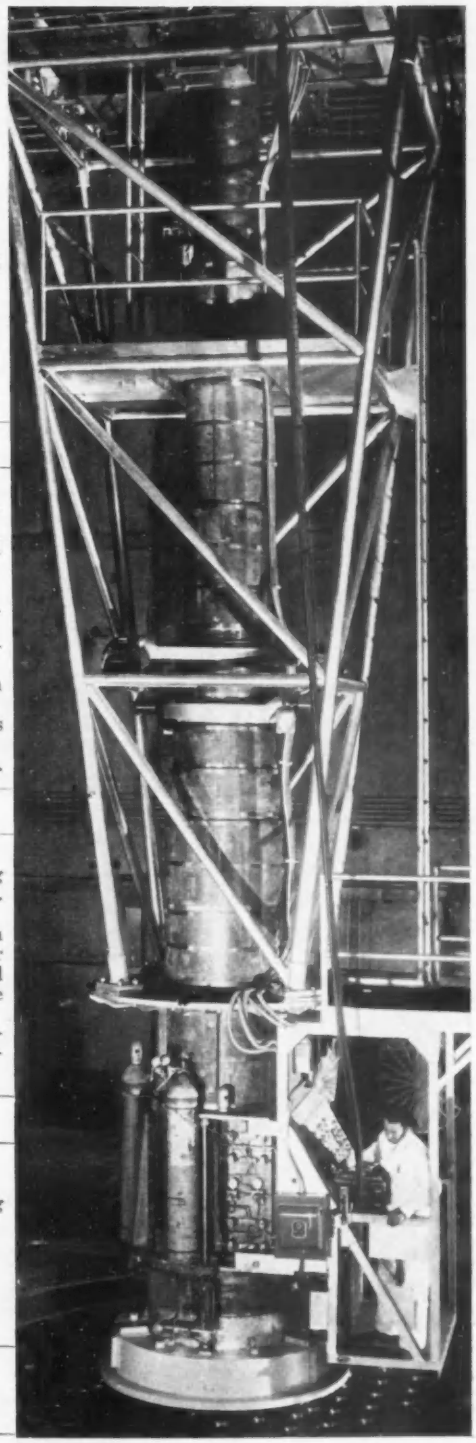

SRE Fuel Handling Cask. The Sodium Reactor Experiment and the Organic Moderated Reactor Experiment are both in successful operation. Plans for several central station plants based on these experimental power reactors are underway. AI is also conducting an advanced power reactor study for Southwest Atomic Energy Associates. Overseas, AI has already sold 5 reactors, and is affiliated with ASEA of Sweden and the new company INTERATOM (with DEMAG, West Germany).

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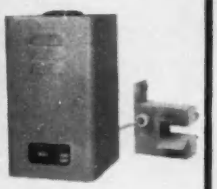

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Model K-1
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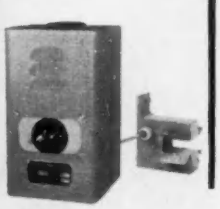

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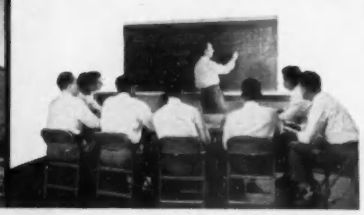

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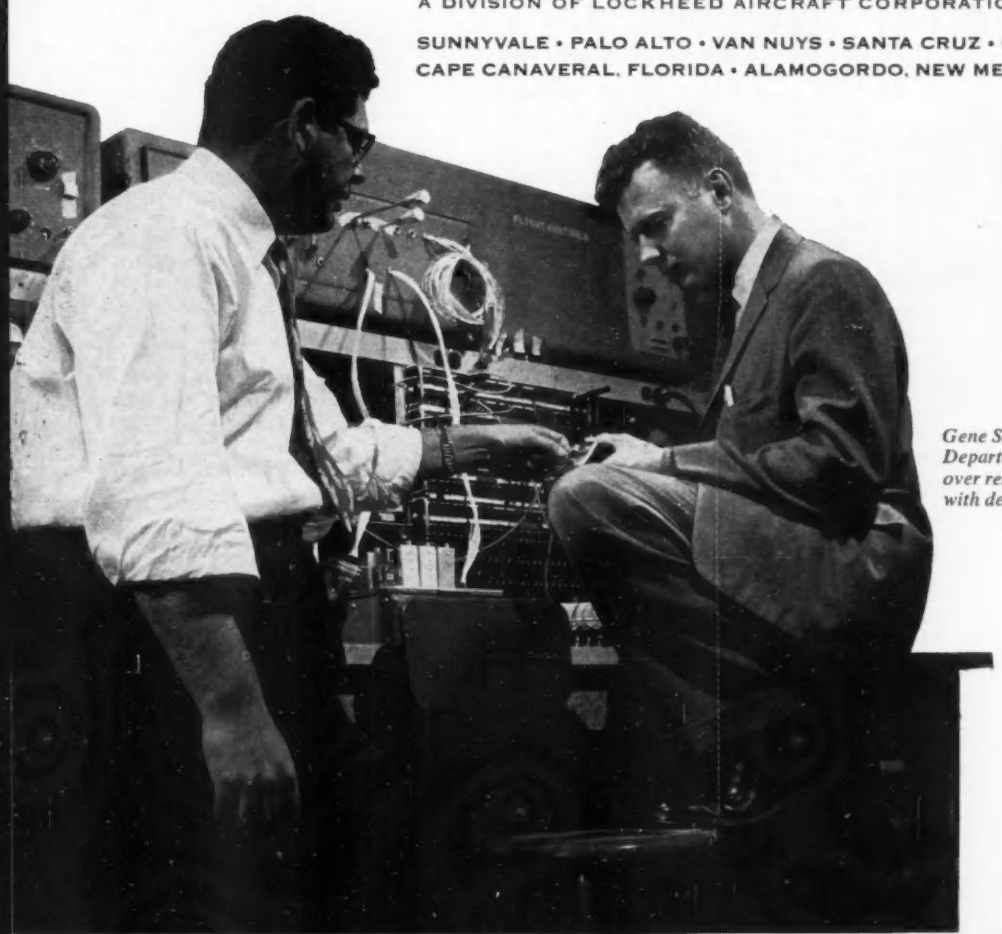

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A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

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A Systems Analysis Predicts Performance, June 1955, 16 pp. This rare case history shows how determining the dynamic characteristics of both the process and the control system (and considering both open to modification) can reduce cost and improve performance. 50 cents.

Digital Application Series. For those readers who would like to fill out incomplete sets of Application Series articles, the following are available as reprints:

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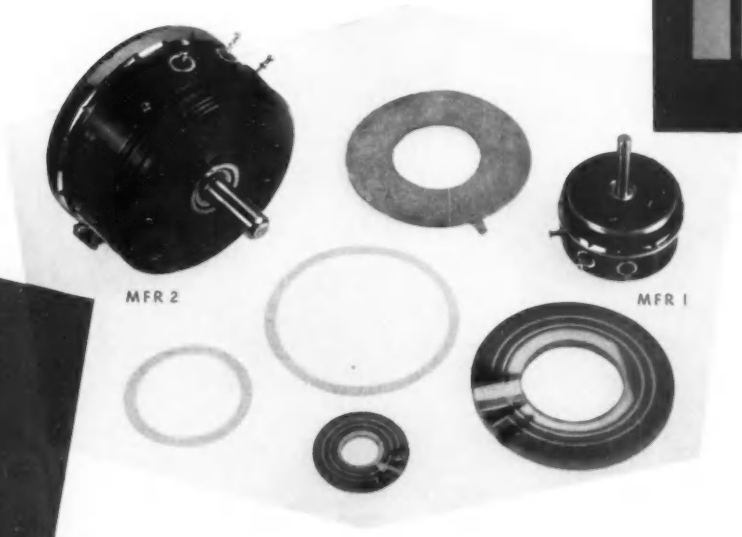

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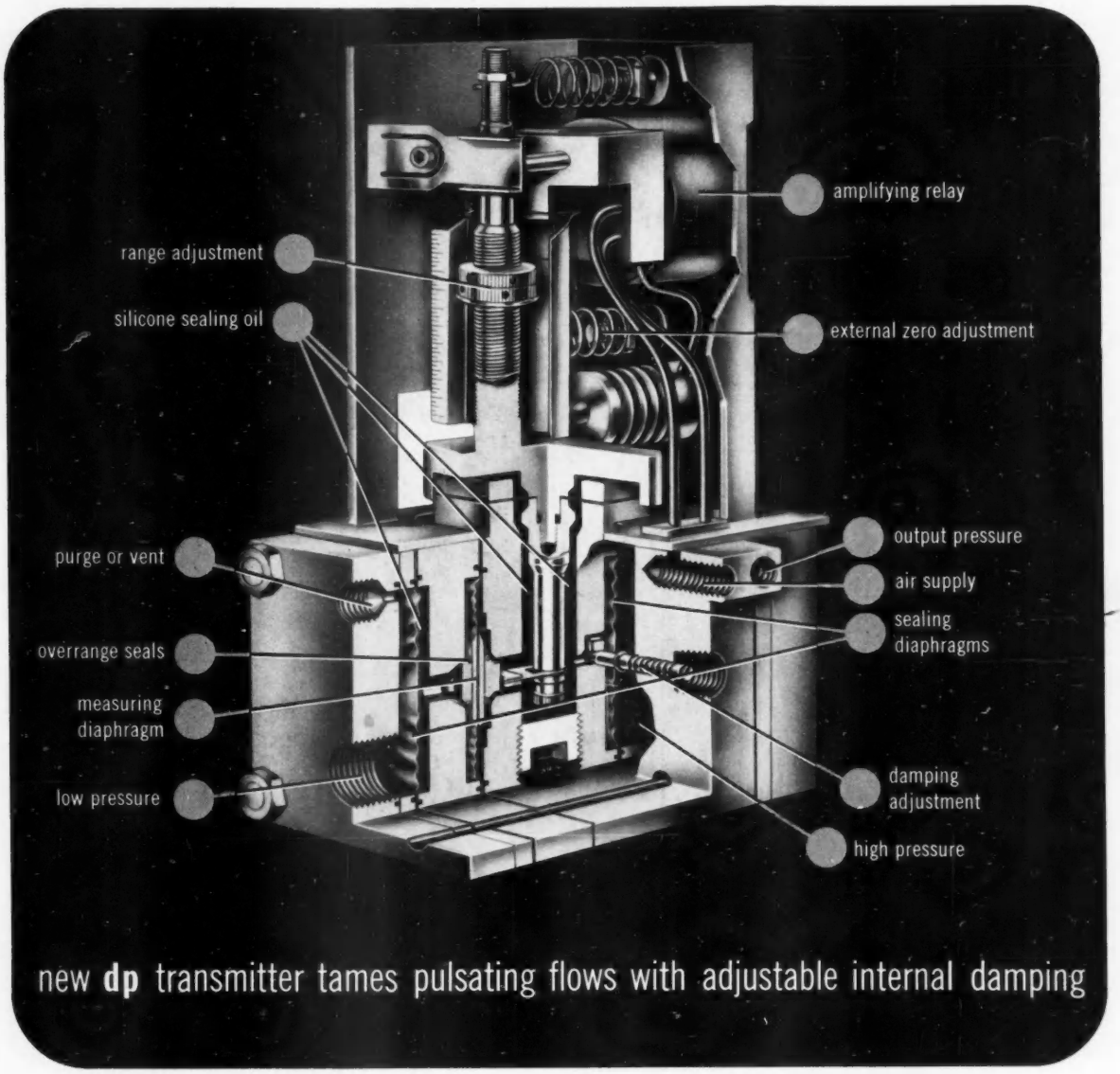

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